Stormwater Management Code

1 Application

This Code will apply in assessing:

- material change of use where:
  - not contained entirely under the roofline of an existing building, or
  - involving land disturbing development, or
  - involving an increase in floor area located on floodable land, or
  - liquid or solid waste will be discharged to land or water
- reconfiguring a lot where:
  - involving land disturbing development, or
  - located on floodable land
- operational works or building works where:
  - involving land disturbing development, or
  - involving the creation of additional impervious surfaces, or
  - located on floodable land, or
  - liquid or solid waste will be discharged to land or water.

2 Using this Code

In using this Code, reference should also be made to Section 1.1—How to use the Codes, at the front of this Chapter.

This Code is only ever called up as a 'secondary' Code by some other Code. This Code is to read as part of that other Code.

Glossary

Detention/retention storage basin: a storage pond, basin or tank used to reduce and attenuate the peak discharge within a drainage system.

Environmental values: the actual or potential function carried out by the water body. For more information on environmental values, refer to the **Management of Urban Stormwater Quality Planning Scheme Policy** or the *Environmental Protection (Water) Policy 1997*.

Floodable land: Land affected by one of the following flood sources:

- Brisbane River
- creeks or waterways
- localised overland flow paths
- designed open channels
- localised flooding
- storm surge (land below 2.5m AHD elevation).

Land disturbing development: any carrying out of building work, plumbing or drainage work, operational work or subdivision where there is potential for accelerated erosion from wind or water and/or the discharge of sediment to drains or waterways.

Localised flooding: includes localised overland flow paths and localised ponding.

Localised overland flow paths are drainage lines that convey stormwater run–off, from any storm, before it enters a creek or waterway network. Overland flow paths, in general, are not part of river, creek or waterway flooding and by nature are dry except during storm events.

Localised ponding occurs in naturally low–lying areas where overland flows from localised storms (of any frequency) collects and creates a temporary detention storage. Water from these ponded areas then slowly drains through stormwater drainage pipes or other waterway networks. These ponded areas are usually dry except during and immediately after storm events.

Major drainage system: part of a drainage system in a catchment which is designed to convey major design storms, e.g. 50 year ARI and 100 year ARI events. The system may comprise open space, floodway channels, road reserves, pavement expanses, overland flow paths, detention basins and lagoons.

Minor drainage system: part of a drainage system in a catchment that controls flows from the minor design storm, e.g. 2 year ARI and 10 year ARI events. The system usually comprises kerbs and channels, roadside channels, gully inlet pits, underground pipes, junction pits, manholes and outlets.

Natural channel design: the basic principles of natural channel design (NCD) are to maintain the hydraulic conveyance requirements of engineered or natural channels, while improving environmental values.

Receiving waters: a body of water (including a wetland) within or downstream of the development that has environmental values. This does not include structures provided for the purpose of stormwater management that have no other secondary functions (e.g. recreation).

Site Based Stormwater Management Plan (SBSMP): a SBSMP identifies potential on and off site (upstream, downstream and adjacent properties) impacts associated with stormwater for a proposal. The SBSMP also identifies the range of stormwater management strategies and actions for water quality and environmental issues.

Stormwater quality best management practices: a range of stormwater management measures that aim to reduce the amount of stormwater run–off and export of pollutants. These practices include source controls, run–off reduction, infiltration controls and pollution interception.

Water quality objectives: measurable long term goals for the quality of receiving waters. For more information on water quality objectives, refer to the **Management of Urban Stormwater Quality Planning Scheme Policy** or the *Environmental Protection (Water) Policy 1997*.

Water sensitive urban design (WSUD): provides a strategy for the conservation and management of water resources through better management of stormwater, for example:

- storage rather than conveyance of stormwater
- maintenance and enhancement of water quality
- water conserving landscaping
- conservation of water related environments
- use of vegetation for stormwater treatment
- localised water supply for irrigation
- use of rainwater tanks for stormwater re–use.

3 Purpose

The purpose of this Code is to:

- integrate planning, design and implementation of the two distinct components of stormwater management, i.e. water quantity and water quality
- prevent or minimise adverse social and environmental impacts on the City's waterways, overland flowpaths, constructed drainage network, Brisbane River and Moreton Bay from stormwater run–off originating from, or passing through development
- achieve acceptable levels of stormwater run–off quality and quantity by applying water sensitive urban design principles in development proposals to maintain and/or enhance the environmental values of the City's waterways and catchments
- ensure that stormwater run–off originating from development is of such quality that environmental values of receiving waters are protected or enhanced
- provide an efficient and cost effective stormwater run–off management system, i.e. a drainage network and detention/retention storage that adequately protects people and the natural and built environments from an unacceptable level of flooding risk.

4 Performance Criteria and Acceptable Solutions

This Code identifies many issues that will require detailed design of systems to mitigate the impacts of development on flooding, water quality and drainage. At the initial application stage it is not intended that detailed design information will be required. However it is crucial to ensure that flooding, water quality and drainage management have been taken into account in development design such that they can be accommodated in the final detailed design.

A Site Based Stormwater Management Plan (SBSMP) is intended to provide adequate information on how these matters are to be dealt with for a particular site. The "notes" contained within each section of the Code outline what information can be provided to demonstrate compliance. The detailed design of the drainage network and stormwater quality best management practices will normally not be required in a SBSMP. Detailed design will usually be required as a subsequent application for operational works or as a condition of approval.

4.1 General

Performance Criteria	Acceptable Solutions
P1 The planning of the stormwater management system must provide for the integrated management of stormwater in order to: • minimise flooding • protect and enhance environmental values of receiving waters • maximise the use of water sensitive urban design principles • maximise the use of natural waterway corridors and natural channel design principles • maximise community benefit • minimise safety risk to all persons	**A1.1** The proposal complies with the **Subdivision and Development Guidelines** **A1.2** A Site Based Stormwater Management Plan (SBSMP) is prepared for all major and minor stormwater management measures. The SBSMP must provide for the following where applicable: • an underground and/or open drain/ overland flowpath network maximising the use of natural channel design and water sensitive urban design principles • make provision for detention/retention storage basins

Performance Criteria		Acceptable Solutions	
			• an Erosion and Sediment Control (ESC) Program where required by Council's **Erosion and Sediment Control Standard** • retention of natural waterway corridors • safety of all persons and risk management measures • an acceptable level of flood immunity
		A1.3	The proposal complies with any Stormwater Management Plan (SMP), Local Stormwater Management Plan (LSMP) or Waterways Management Plan (WMP) prepared by Council *Note: the **Subdivision and Development Guidelines** provide guidance on the level of information required for different development types*

4.2 Flooding

Performance Criteria		Acceptable Solutions	
P1	The proposed stormwater management system or site works must not adversely impact on flooding or drainage of properties that are upstream, downstream or adjacent to the subject site	A1	The proposal meets the requirements of Council's **Subdivision and Development Guidelines** and does not result in an increase in flood level or flood duration on upstream, downstream or adjacent properties *Note: compliance with this acceptable solution can be demonstrated by the submission of a hydraulic and hydrology report (as part of a SBSMP) identifying potential flooding impacts on upstream, downstream or adjacent properties*
P2	The drainage network must provide capacity to safely convey stormwater run–off resulting from relevant design storm events taking into account increased run–off from roof drainage	A2.1	The design demonstrates that a drainage network will be provided that will comply with Council's **Subdivision and Development Guidelines** *Note: compliance with this acceptable solution can be demonstrated by identifying the conceptual drainage requirements for the proposal in a SBSMP*
		A2.2	The design allows sufficient area to provide for a drainage network that will comply with Council's **Subdivision and Development Guidelines** *Note: compliance with this acceptable solution can be demonstrated by the submission of a hydraulic and hydrology report (as part of a SBSMP) identifying the area required to accommodate the drainage network*

Performance Criteria		Acceptable Solutions	
P3	Development design (including any carparking areas) must reduce property damage, provide flood immune access to the property and, where applicable, ensure the safety of all persons by ensuring that the development levels are set above the relevant design flood level or storm surge level	**A3.1**	All development (including ancillary structures and carparking areas) is located above minimum flood immunity levels in accordance with Council's Subdivision and Development Guidelines *Note: compliance with this acceptable solution can be demonstrated by the submission of a hydraulic and hydrology report identifying flood levels and development design levels (as part of a SBSMP)*
		A3.2	Road access is provided in accordance with the flood immunity levels identified in Council's **Subdivision and Development Guidelines** *Note: compliance with this acceptable solution can be demonstrated by the submission of a hydraulic and hydrology report identifying flood levels and development design levels*
P4	Any channel works that are part of the development, major drainage works or flood mitigation works must maintain and/or enhance the environmental values of the waterway corridor or drainage corridor	**A4**	Design and construction of channel works incorporate water sensitive urban design and natural channel design features which will comply with: • Council's **Subdivision and Development Guidelines**, and • where applicable any SMP, LSMP or WMP prepared by Council *Note: compliance with this acceptable solution can be demonstrated by the provision of conceptual details of any channel works (as part of a SBSMP)*
P5	Erosion treatment works along waterway banks and associated drainage structures must maintain or enhance the environmental values of waterways	**A5**	Design and construction of erosion treatment features incorporate natural channel design features which will comply with: • Council's **Subdivision and Development Guidelines**, and • Council's **Urban Creek Erosion—Guidelines for Selecting Remedial Works** *Note: compliance with this acceptable solution can be demonstrated by the provision of conceptual details of any erosion treatment works (as part of a SBSMP)*
P6	Bridges and culverts provided for flood immunity to minimise traffic disruption must improve the safety of all people and allow for fauna movement and recreation corridors where these needs are identified	**A6**	The design complies with Council's **Subdivision and Development Guidelines** *Note: compliance with this acceptable solution can be demonstrated by the provision of conceptual details of any bridge or culvert works (as part of a SBSMP)*

Performance Criteria		Acceptable Solutions	
P7	The design and construction of detention and retention storage features must: • achieve acceptable impacts on environmental values • provide for recreational use where possible • achieve acceptable risk to all persons' safety and property	**A7**	The design complies with Council's **Subdivision and Development Guidelines** and where applicable any SMP, LSMP or WMP prepared by Council *Note: compliance with this acceptable solution can be demonstrated by the provision of conceptual details of any detention and retention storage features (as part of a SBSMP)*

4.3 Water Quality and drainage

For this section:

Low Risk Development is any development other than that identified as high risk development.

High Risk Development is any of the following:

- development in a waterway corridor or a wetland as identified on the Planning Scheme Maps
- multi–unit dwellings or commercial uses with an impermeable surface area (not including roof area) in excess of 2,500m²
- subdivision where at least 6 lots are involved
- industry that have at least 1,000m² in uncovered storage/working space
- industry listed in Industrial Areas—Schedule 2
- uncovered carparks with at least 100 spaces.

Performance Criteria		Acceptable Solutions	
Low risk development			
P1	Water quality impacts must be minimised using best practice techniques	**A1.1**	The design provides for stormwater quality best management practices that are sufficient to treat the target pollutants and will comply with the Council's **Subdivision and Development Guidelines** *Note: compliance with this acceptable solution can be demonstrated by indicating the areas that are to be set aside for water quality best management practices. For most development this can be achieved by determining pollutant loads using hand calculations as set out in Council's* ***Guidelines for Pollutant Export Modelling in Brisbane*** *and identifying the type and size of stormwater quality best management practices based on their efficiencies identified in Council's* ***Subdivision and Development Guidelines***
		A1.2	Stormwater quality best management practices are designed, constructed and maintained in accordance with Council's **Subdivision and Development Guidelines** *Note: compliance with this acceptable solution can be demonstrated by providing conceptual detail of how stormwater quality will be managed (as part of a SBSMP)*

Performance Criteria	Acceptable Solutions
P2 Release of sediment laden stormwater is minimised	**A2** All development complies with Council's **Erosion and Sediment Control Standard** *Note: compliance with this acceptable solution can be demonstrated by providing conceptual details of how the requirements of Council's* ***Erosion and Sediment Control Standard*** *will be met (conceptual SBSMP). This will generally be conditioned and may require the submission of a subsequent detailed SBSMP for operational works*
High risk development	
P3 Environmental values and water quality objectives of receiving waters within or downstream of the proposal are protected or enhanced	**A3.1** Relevant water quality objectives for receiving waters are identified and site specific discharge standards met *Note: compliance with this acceptable solution may be demonstrated by following the process outlined in the* ***Management of Urban Stormwater Quality Planning Scheme Policy****. This can be documented in a SBSMP* **A3.2** The design provides for stormwater quality best management practices that are sufficient to treat the target pollutants and will comply with the Council's **Subdivision and Development Guidelines** **A3.3** Stormwater quality best management practices are designed, constructed and maintained in accordance with Council's **Subdivision and Development Guidelines** *Note: compliance with this acceptable solution can be demonstrated by providing conceptual detail of how stormwater quality will be managed (as part of a SBSMP)*
P4 Release of sediment laden stormwater is minimised	**A4** All development complies with Council's **Erosion and Sediment Control Standard** *Note: compliance with this Performance Criteria/Acceptable Solution can be demonstrated by providing conceptual details of how the requirements of Council's* ***Erosion and Sediment Control Standard*** *will be met (conceptual SBSMP). This will generally be conditioned and may require the submission of a subsequent detailed SBSMP for operational works*

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1.0 INTRODUCTION

This chapter should be read in conjunction with the Water Quality Management Guidelines in Part C of this document. The planning, design and implementation of stormwater drainage should integrate the two distinct components of stormwater management, ie water quantity and water quality. The stormwater drainage system should:

- Prevent or minimise adverse social, environmental, and flooding impacts on the City's waterways, overland flow paths and constructed drainage network.
- Ensure that the design of channel works as part of the development maximises the use of natural channel design principles where possible.
- Achieve acceptable levels of stormwater runoff quantity and quality by applying total water cycle management and water sensitive urban design principles.

Unless stated otherwise in this document, the planning and design of urban stormwater drainage systems should conform to the requirements of the latest version of *Queensland Urban Drainage Manual* (QUDM).

2.0 GENERAL

2.1 LAWFUL POINT OF DISCHARGE

It is a matter of settled law that any owner of a property through which stormwater flows who develops or alters their property in any way owes a duty of care to any property owner receiving those stormwater flows to ensure that any additional flows caused by the development do not cause unreasonable damage. The duty of care extends not just to the owners of immediately adjoining lands but also to owners downstream from the adjoining land.

That duty of care can be satisfied by:

- Diverting the flows around the property that would otherwise be adversely affected.
- Obtaining the consent of the downstream owner/s to that flow.
- Providing infrastructure on the downstream property that mitigates the adverse effects of the increased flow.

When land is subdivided or developed, the roof and surface water runoff from that land and any external catchment (through the development site) must be discharged to a lawful point of discharge acceptable to Council.

Designs which result in concentration of water onto an adjoining property or rely on the construction of drainage through an adjoining property will not be accepted unless written approval is obtained from downstream owner/s of any affected property. **Evidence of a lawful point of discharge should accompany the engineering drawings for any approval to be given**. If a satisfactory lawful point of discharge cannot be achieved the development cannot proceed. The lawful point of discharge and full details at the outlet should be shown on the engineering drawings.

The effects of the discharge (up to and including the Q_{50} or Q_{100} storms) from a development site on other properties by virtue of increased runoff, increased concentration of runoff, change to the existing overland flow, or change to the existing point of concentration, must be assessed in the design. Any of these effects as well as increased flow depth for the same Average Recurrence Interval (ARI) will require a lawful point of discharge to be obtained. In addition to obtaining the downstream owner's permission, easements may be required over the drainage systems within the downstream properties.

The **lawful points of discharge** may be one of the following, depending on the site situation.

1. To concrete kerb and channel, gullies or existing enclosed stormwater drainage system abutting the allotment. The applicant should also demonstrate compliance with the permissible flow width, flow depth and depth velocity product.
2. To the road reserve provided the concentration of stormwater does not adversely affect the drainage capacity of the road and/or adjoining properties.
3. Through adjoining private property at the rear of the allotment to concrete kerb and channel or existing enclosed drainage system providing written permission is obtained from the downstream adjoining property owner.
4. To an existing enclosed drainage system (excluding any foul water lines) within 50 metres of the site provided the system has the capacity required. Calculations should incorporate future upstream developments.
5. To concrete kerb and channel and thence to a new stormwater inlet to be provided by the Developer at a location removed from the site.
6. To an existing stormwater drain within the property or by written permission of the adjoining property owner, to a stormwater drain in adjoining properties.
7. To kerb and channel or existing enclosed drainage system higher than the allotment from a drainage pit within a site by pumping. This method will only be considered in developments pertaining to material change of use, refer to Section 2.5.

2.2 STORMWATER OUTLETS

The publication *Stormwater Outlets in Parks and Waterways Guidelines* (Brisbane City Council, 2003) sets out the requirements for stormwater outlets in parks to achieve the best possible balance between the diverse competing opportunities and the constraints of parks, waterways and wetlands.

The applicant should not assume that drainage channels, overland flow paths, drainage outlets, energy dissipators or stormwater detention/polishing basins will automatically be permitted in public space (newly created Council asset or existing Council asset). Further, it is unlikely that filling of existing natural drains/watercourses would be permitted without Council approval. Prior to the design of any stormwater discharge facility into Council controlled land, the applicant should consult with the relevant Development Assessment Officers, usually the Open Space Planner or Ecologist, to:

- Ensure that the proposal is accepted.
- Ensure that the proposal complies with the park character plans and park objectives.
- Ensure that the proposal complies with the Park Code and Waterway Code of the *Brisbane City Plan*.
- Determine the levels of impact assessment required.

Stormwater outlets in any public space (existing or newly created Council asset) must be addressed at the initial application (conceptual design) stage, and not be deferred to the operational works assessment stage, as the method of stormwater conveyance and treatment could influence the development's design, layout and cost.

CHAPTER 2 STORMWATER DRAINAGE

The applicant must submit concept drawings to Council for initial review at the time of assessing the development application and obtain subsequent preliminary approval during this time. Detail calculations and drawings can be submitted at the later stage of operational work assessment. A site inspection will probably be required prior to construction.

Where the stormwater discharge is across a public space designated for active recreation, piped drainage must be provided for the minimum Q_1 storm to ensure that the function of the amenity is not diminished.

Where the open space function is not governed by spatial constraint and the catchment area exceeds 30 hectares, the opportunity to construct or enhance a natural self sustaining drainage channel (as opposed to enclosed pipe drainage) must be maximised.

Where piped drainage is installed, and wherever practical, vegetated swales may be required downstream from the pipe outlet to provide additional treatment to stormwater runoff. Vegetated swales should be placed along the interface of the riparian vegetation and the park. The location of discharge point at the riparian corridor must be selected to minimise disturbance and intrusion.

2.3 PIPE CONNECTION TO COUNCIL INFRASTRUCTURE

Permits

A permit must be obtained from Council before any pipe connection can be made to Council infrastructure. Prior to backfilling, the works at the connection must be photographed from different angles to gain a full picture of the connection, and inspected by a Registered Professional Engineer in Queensland. The inspection report and photographs must be forwarded to Council for consideration and records.

Connection to kerb and channel

Refer to Section 5.1.2 and Section 5.2.1 for prefabricated kerb adaptors and hot dipped galvanised RHS.

Connection to existing stormwater pipe

This method can be used where the diameter of the entry pipe is less than 200 mm, and the host pipe diameter is at least 4 times larger than the entry pipe diameter. The connection should be made in the top half diameter of the host pipe by core drilling (for steel reinforced concrete pipe) or installing a saddle junction (for fibre reinforced concrete or steel reinforced concrete pipes or polypropylene/polyethylene pipes). The entry pipe must be installed flush with the internal wall of the host pipe and the connection sealed using an appropriate epoxy resin in a manner acceptable to Council and the pipe manufacturer.

Note: It is unacceptable to break into the existing pipe by physically punching a hole with a hammer or jackhammer. This method can create a hole that is irregular and oversized. The exposed reinforcement and unnecessary spalling to the inside of the pipe surface can damage the pipe structure.

Connection to existing gully pit

This method can be used where the diameter of the entry pipe is ≤ 300 mm and surcharge of the gully does not occur. The connection should be repaired using cement mortar and finished flush with the internal wall. Unless approved otherwise by Council, the pipe connection must be located below the lintel and where the entry pipe diameter exceeds 200 mm, this pipe must be installed at the pit invert.

Connection to existing manhole

This method can be used where the diameter of the entry pipe is ≤ 675 mm. The connection must be repaired using cement mortar and finished flush with the internal wall. A minimum 150 mm clear distance is required between the inlet pipes. For complex manholes with more than two inlet pipes, benching is required to the floor of the manhole (to half the diameter of the outlet pipe). For the larger diameter entry pipes, new manholes must be constructed.

2.4 EASEMENTS

2.4.1 When are Easements Required

Drainage easements are corridors registered on a certificate of title for the purpose of underground drainage pipes and/or overland flow paths. Any construction within the drainage easement and/or near/over stormwater infrastructure must be avoided whenever possible. This approval process is outlined in Section 2.6 Building Over/Near Stormwater Facilities. Pipe drainage easements are required over any pipe 225 mm diameter or larger.

2.4.2 Types of Easements

Roofwater reticulation

Roofwater drainage reticulation pipes of 225 mm and 300 mm diameter must be provided with an easement 1.5 m wide in favour of Council. Roofwater reticulation drainage of 150 mm diameter (ie servicing up to 3 single house lots of nominal 180 m^2 roof area each) does not require an easement.

Underground pipe drainage

This easement allows for the construction and/or maintenance of underground drainage. Approval to build over an easement should be in writing and does not alter the terms of the easement agreement.

The minimum easement widths required for underground pipe drainage other than roofwater lines must be the greater of 3.0 m or the outside pipe diameter/culvert box width plus 1.0 m clearance distance from edge of pipe/culvert. For example, 3 m easement widths apply to single pipes 300 mm to 900 mm diameter.

Open cut drainage

This type of easement allows for the construction and maintenance of an open drain or channel within the easement. The easements must be wide enough to incorporate berms along the top of open channel. See Section 5.6.7 for berm requirements.

Overland flow

This provides for passage of stormwater along the easement and prohibits the erection of structures, the alteration of surface levels, and any activity within the easement which may obstruct the flow of storm runoff, eg debris retentive fences, landscaping, walls, filling. The easement must be the full design flow width and vegetated or paved to prevent potential scouring.

Access

Access easements permit Council to have access from a surveyed road to an easement to facilitate construction and/or maintenance of the drainage facility. (Unless agreed otherwise by the property owner, the access is usually the most direct route through the property.) This will normally form part of all underground open cut and overland flow easements.

Combined underground/aboveground drainage

Combinations of the above easement types will often be required eg underground and overland flow where there is an overland flow associated with piped drainage.

Portion of land subject to waterway inundation

A waterway (including those indicated on the Planning Scheme Maps) is defined as any element of a river, creek, stream, gully or drainage channel, including the bed and banks. Easement over the 100y ARI inundation extent is required to preserve hydraulic conveyance and floodwater storage.

2.4.3 Variation to Easement Terms

There is no statutory procedure for the variation of a registered easement except by decision of Council. A variation or modification of the terms of the easement agreement can be achieved by surrendering the existing easement and by the granting of a new easement. All costs are the responsibility of the applicant.

2.4.4 Extinguishment of Easements

To have an easement extinguished, the owner of the property has to obtain the agreement of the grantee (ie the Council) to execute a surrender of the easement and have that surrender document registered by the Registrar of Titles. Council may also wish to recover previously paid compensation monies at the present market value. All costs are the responsibility of the applicant.

2.5 PUMPED STORMWATER DRAINAGE

2.5.1 General

A pumped drainage system is only permitted in developments pertaining to material change of use such as Community Titles Scheme, commercial and industrial developments. Council will only consider a pumped stormwater drainage system if:

- Council is satisfied all other avenues have been exhausted.
- Letters of refusal are received from all property owners through which the roofwater line could be taken by gravity to the street, including acknowledgement that significant overland flow will occur at times of power or mechanical failure.
- It is part of a comprehensive stormwater recycling system.

Further, the applicant must satisfactorily address the following requirements.

- A suitably experienced Registered Professional Engineer in Queensland (RPEQ) should be engaged to prepare and certify the design. Further the RPEQ should inspect the works during construction to ensure that the design intent is achieved and certify same. Refer to Chapter 1 of Part D of this document.
- Demonstrate that the overspill can take the form of sheet flow and reflect pre-development conditions when the pump capacity is exceeded.
- Demonstrate that in the event of malfunction, the consequences are not catastrophic. For example overflows should leave the site in a safe manner and not inundate habitable or non-habitable areas within and external to the site.

2.5.2 Pumps and Storage

The pump well storage and pump capacities must be designed for the minimum 10 year ARI critical storm burst. The critical storm burst is the storm duration that dictates the maximum active storage size, and this storm duration is usually independent of the sub-catchment time of concentration. Typically pumping and storage characteristics during smaller storm events (eg 2, 5 and 10 year ARI) for a range of duration (say up to 2 hours) would need to be investigated, to ensure that the pump operates within the manufacturer's recommendations.

In some instances the 10 year ARI design event maybe inadequate. For example, pumps may need to be sized for more extreme storm events when dewatering basement carparks or where overland sheet flows cannot be achieved.

Council prefers that the pumped systems be discharged directly to a gully, a manhole or a drainage line. Direct discharge to a kerb and channel is not permitted. Where the kerb and channel is the only lawful point of discharge, the outlet from the pump should feed to a storage manhole which then drains by gravity to the kerb and channel. Regardless of these disposal methods, a check of road capacity and existing drainage system is required to demonstrate that there are no adverse impacts.

Storage areas can be a combination of underground and aboveground areas, for example, shaped car park or landscaped area to hold water till pumping system restarts. However care needs to be exercised with aboveground storage area that public safety or amenity is not compromised.

The pump well design must consider the following factors.

- Minimise deposition of solids.
- Excessive foaming and air entrainment (usually caused by stormwater dropping from a high level inlet pipe) in the wet well to be avoided.
- Structural design to resist uplift, soil and water pressures.
- Suitable openings to enable pump removal, and for electrical and pipework access.
- Sufficient space to be provided around the chamber for maintenance access and sufficient headroom for lifting tackle to be erected so as to raise the pumps if necessary.

The pump design must consider the following factors.

- In addition to the operating duty pump, an equivalent standby pump (ie of equal size to duty pump) must be installed to safeguard against mechanical failure.
- In order to assure reliability of the standby pump, the pumping system must be set up by automatic rotation to ensure that the hours run by both the duty and standby pumps are approximately similar.
- The most likely stormwater pump station configuration is usually the submersible wet well centrifugal type pumps normally employed in the wastewater industry. These pumps are available off the shelf and come in an extensive range of sizes and configurations. They are also not self priming ie they require a positive head at their inlet in order to commence pumping without initial priming (removal of air from the pump casing).
- Pump sizing calculations must incorporate the system resistance, pump duty point, frequency of pump motor starts, etc.

The property owner is responsible for all costs associated with installation, operation and maintenance; and is liable for all damages as a result of system malfunction.

2.6 BUILDING OVER/NEAR STORMWATER FACILITIES (BONSW)

2.6.1 General

The primary objective of BONSW approval is to protect existing stormwater facilities from damage. It is preferred that buildings and structures are located clear of stormwater facilities either on the existing or diverted alignment. In the context of this document stormwater facilities are defined as any component, whether by way of natural topography (eg gully or depression forming the overland flow path) or constructed infrastructure (eg open cut channel, pipe, conduit, manhole), that forms part of a stormwater drainage system. BONSW approval must be obtained from Council prior to the issuance of any building/development approval.

Approval of building/development applications without due consideration of the likely adverse impacts on stormwater facilities can often lead to undesirable outcomes including:

- Nuisance flooding. This can occur when a slab on ground building is constructed in or across the overland flow path thereby blocking flows and leading to flow diversion to neighbouring properties or when the floor level is set below an acceptable inundation level from adjacent overland flow paths.
- Degradation or damage to the stormwater infrastructure. This can occur when the stormwater infrastructure (eg pipe, manhole, pipe trench) is disturbed during construction, or when additional loads are transferred to the pipe system eg through inappropriate foundation design, or accidental damages incurred due to lack of knowledge of the presence of any underground infrastructure.
- Unexpected costs and time delays. This can occur when stormwater infrastructure is discovered during advanced excavation thus requiring redesign of foundation, or repair costs to damages sustained during construction.
- Inadequate provision of accessibility for future maintenance.
- Development of properties in overland flow paths where insufficient flood free land is available for a building pad.

For development constraints on aboveground facilities, refer to Chapter 1 of Part A of this document. Building work proposed over or near underground stormwater facilities (BONSW) is not permitted under one or more of the following criteria.

- The creation of a new lot (typically reconfiguring a lot in an established area eg 1 lot into 3 lots) containing stormwater pipe infrastructure outside the statutory boundary clearances[1].
- It is viable to relocate stormwater facilities clear of the development without creating adverse hydraulic impacts.

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[1] The statutory boundary clearances are generally in accordance with the Building Act 1975. For the purpose of assessment, these measurements are taken to be:
- 6.0 m road boundary clearance.
- 1.5 m side and rear boundary clearances.

2.6.2 Assessment Triggers

For **aboveground stormwater facilities** with or without drainage easements, a Building Over/Near Stormwater (BONSW) application will be required if the site is subject to any one or more of the following conditions.

- Any proposed works contravening the drainage easement terms. The easement conditions usually prohibit any part of the building extending over the drainage easement.
- Open cut channel for the passage or conveyance of stormwater traversing the site.
- Overland flow path traversing the site, whether natural or excavated/engineered grassed or landscaped swales.
- Overland flow path over underground drainage system on site, as commonly encountered in city streets and developments such as carparks, estates and shopping centres.
- Combined underground drainage and overland flow on site. This is the most common basis for conveyance of stormwater in new estates whereby minor flows are piped and excess flow is channelled via an engineered or landscaped topography.
- Stormwater pipes strapped to the underside of building basements or aboveground pipes fixed to roof and wall. Aboveground pipes can occur on rare occasions where it is not possible to relocate the pipe clear of the structure, generally because the building is constructed right to the side boundaries. The risks of consequential pipe failure should be assessed. (Note: In a few areas of Brisbane, stormwater drains are visible and in some cases partially above surface levels).

For **underground stormwater facilities** with or without drainage easements and where pipes or conduits are greater than or equal to 150 mm in diameter or width, a Building Over/Near Stormwater (BONSW) application will be required if the site is subject to any one or more of the following conditions.

- Any proposed works contravening the drainage easement terms.
- Any earthworks (filling or excavation) proposed directly over or adjacent to the stormwater drainline or manholes that will result in changes to surface levels or loading conditions over these stormwater facilities. (Note: Typical minimum covers over pipes are 600 mm in non-trafficked areas, 750 mm in vehicular trafficked areas, 300 mm under bridging or concrete slabs.)
- Any building work proposed over the stormwater drainline or manholes. This is generally not permitted, refer Section 2.6.1 for details.
- Any proposed footing system that is bored or excavated (eg beams, slabs, footings, and piers) within 2 metres (edge to edge distance) of the stormwater drainline or manhole.
- Any proposed footing system that is driven or vibrated or jacked (eg piles and piers) within 6 metres (edge to edge distance) of the stormwater drainline.
- Any proposed works that will affect the structural integrity of the drainline or its trench.
- Proposed changes to the loading conditions on an existing manhole cover, for example, changing the use of a non-vehicular trafficable area to a vehicular trafficable area.
- Proposed use of rock bolts or ground anchors within 2 metres of the stormwater drainline.
- Proposed property access width of less than 2 metres from the front entrance or access road to any manhole or property connection located on site.

- Proposed driveways or concrete pavements over manholes or property connections.
- Clashing of services or utilities (other than sewers) with the stormwater drainline that may affect the structural integrity of the stormwater drainline or its trench, or sewers larger than 150 mm diameter crossing any stormwater drainline.

The following information must accompany the BONSW application.

- Payable fees.
- Photographs if desired.
- Site plan (layout and elevation) showing existing and/or proposed elements such as location, size, and depth of pipe and manholes; structure clearances; foundation details, etc. (Note: Bridged footing details should be designed and certified by a suitably experienced Registered Professional Engineer Queensland).
- Title search details to confirm the presence or absence of any drainage easement.
- If a drainage easement is present, the applicant must supply a copy of survey plan and title deed detailing the extent and terms of the easement. The applicant can obtain these details from the Land Interests and Titling Office, Queensland Department of Natural Resources and Mines.
- Appropriate hydrologic and hydraulic assessments by a suitably qualified and experienced Registered Professional Engineer in Queensland (RPEQ). A hydraulic grade line analysis report is required to assess head losses and surcharge characteristics, in particular, when the proposal involves the raising and lowering of manholes or where additional manholes and bends are added to the stormwater drainage system on a diverted alignment.
- Pre construction pipe surveys. (Note: The post construction and any subsequent pipe surveys should be submitted prior to the issuance of a Certificate of Classification (where there are no contributed assets) or prior to the acceptance Off Maintenance (where contributed assets are involved)).

2.6.3 Pipe Surveys

<u>General</u>

Pipe surveys are required to determine the pipe condition at the pre and post construction stages. (Note: In older areas of Brisbane, some 150 mm and 225 mm diameter pipes discharge from street gullies, traversing private properties). The applicant must submit both a hardcopy report and a video display of the closed circuit television camera (CCTV) inspection.

The CCTV inspection report and video must be viewed by an RPEQ prior to submission to Council. Any additional defects should be identified and remedial measures recommended by the RPEQ. Remedial measures for all additional defects must be submitted to Council for approval. Once the remedial measures have been completed, a follow up survey is required to demonstrate that they have been carried out to Council's satisfaction.

To achieve a high level of consistency, it is recommended that the same contractor be engaged to undertake both the pre and post construction (and any subsequent) surveys. All costs must be borne by the applicant.

CCTV inspections of pipes can be arranged through Local Asset Services, Brisbane City Council (Contact: Coordinator Asset survey, officer code LCAS, telephone 3403 8888) or other service providers. Any person entering Council's stormwater drains must fulfil the requirements of the Workplace Health and Safety Act 1995 (eg confined space training).

Survey protocol

The CCTV pipe survey must conform to Brisbane City Council's standard inspection and reporting protocols, achieved by using the WinCan CCTV data capture and asset management software customised to Council standard format.

If longitudinal cracks are observed at the obvert of the pipe, particular attention should be paid to the invert and the 3 o'clock and 9 o'clock positions for evidence of crushing. All cracks should be closely monitored whilst the camera is in motion. All joints should be fully scanned (over 360°) whilst the camera is stationary. Particular attention should be paid to possible infiltration at joints and connections. All connections should be closely inspected; their diameter, type and position being recorded.

The video display and hardcopy report should show all the faults, features and connections in the line. The typical example given below illustrates the reporting format to Council's standard procedures and fault codes.

Manhole 133 → Manhole 132 (upstream), Line 125, 900 mm cast-in-situ concrete.
Distance:

1.6 m	-	start survey
29.0 m	-	spalling, position 9 o'clock, width 50 mm, length 100 mm, depth 40 mm
49.3 m	-	minor faulty 100 mm connection, position 1 o'clock
53.7 m	-	protruding 150 mm connection, position 12 o'clock, depth 400 mm
70.8 m	-	change in pipe material, length 1500 mm
70.8 m	-	minor longitudinal crack, position 12 o'clock, depth 1000 mm
73.2 m	-	minor tree roots up to 25%, position 3 o'clock, length 3000 mm
80.4 m	-	up to 25% debris, width 200 mm, length 1500 mm, depth 20 mm
85.0 m	-	major eroded invert, length 13500 mm, width 700 mm, depth 100 mm
105.0 m	-	survey completed

2.6.4 Pipe Rehabilitation

Following assessment of the pre construction pipe survey information, Council will advise the applicant if there are any repairs or future works required prior to construction within the site. Council may require that degraded pipe be repaired, replaced or diverted as part of the BONSW approval conditions. Council may also seek appropriate cost contribution from the applicant.

2.6.5 Access and Clearance

General

The provision of an unimpeded access corridor to the stormwater infrastructure is required to facilitate pipe maintenance, relining, rehabilitation or replacement. It is preferred that structures are located clear of aboveground and underground stormwater facilities either on existing or diverted alignment (refer Case 1). Where there is combined underground and aboveground drainage facilities, the more stringent access and clearance criteria will apply.

Manhole clearance

Manholes must remain accessible when the development is completed ie a minimum 2.0 m radius from centre of cover must be maintained. Suitable and permanent access must be provided from the front boundary or access road to all manholes without having to pass through buildings. The access way must be at least 3.0 m wide and achieve a minimum height clearance of 2.5 m. Manholes must be raised or lowered to match the finished surface level.

Access corridor over pipe

Where the building structure is built over existing stormwater pipes, a minimum 3.0 m wide corridor (or the greater dimension comprising the nominal pipe diameter plus 1.0 m horizontal clearance each side) should be provided over the affected pipe length to facilitate future pipe maintenance and replacement.

For suspended structures over pipes (refer Case 3), a 2.5 m undercroft[2] height clearance (3.0 m height if finished floor levels are referenced) is also required. Where the vertical height clearance cannot be achieved or for slab on ground structures (refer Case 2), piers (founded at least 0.6 m below the pipe invert and 1 m horizontally clear of the pipe) are required to support a minimum 3.0 m span bridging slab. The bridged foundation allows the option of future pipe replacement by tunnelling or boring.

Foundation clearance

An adequate buffer zone is required between the edge of the foundation system and the edge of the stormwater infrastructure to minimise structural damage during excavation, boring or piling operations. The following minimum horizontal clearances may need to be increased if it is anticipated that the pipe bedding will be affected.

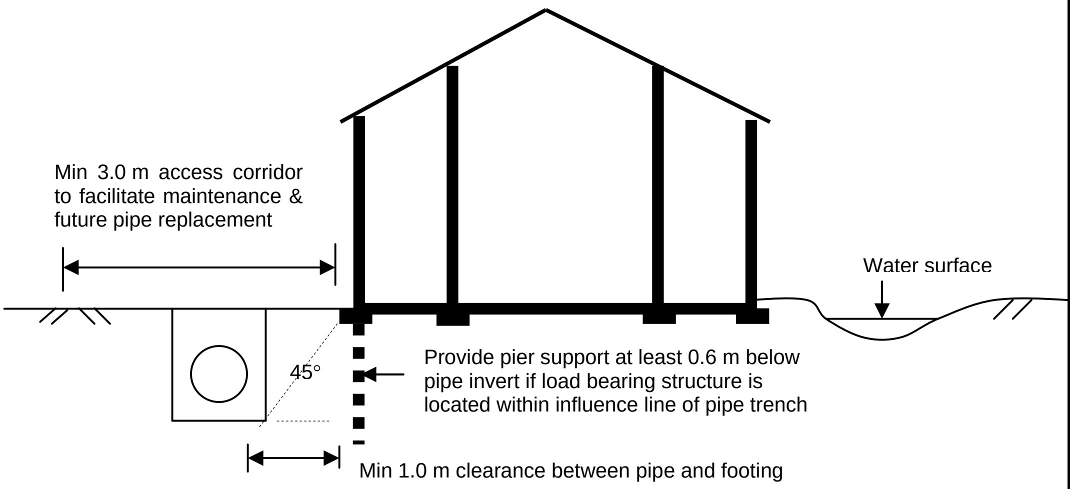
- 1.0 m clearance applies to an excavated footing system such as piles, beams and pad footings, excavated by backhoe or similar.
- 1.0 m clearance applies to bored piers.
- 6.0 m clearance applies to driven or vibrated or jacked piles.

Aboveground stormwater facilities

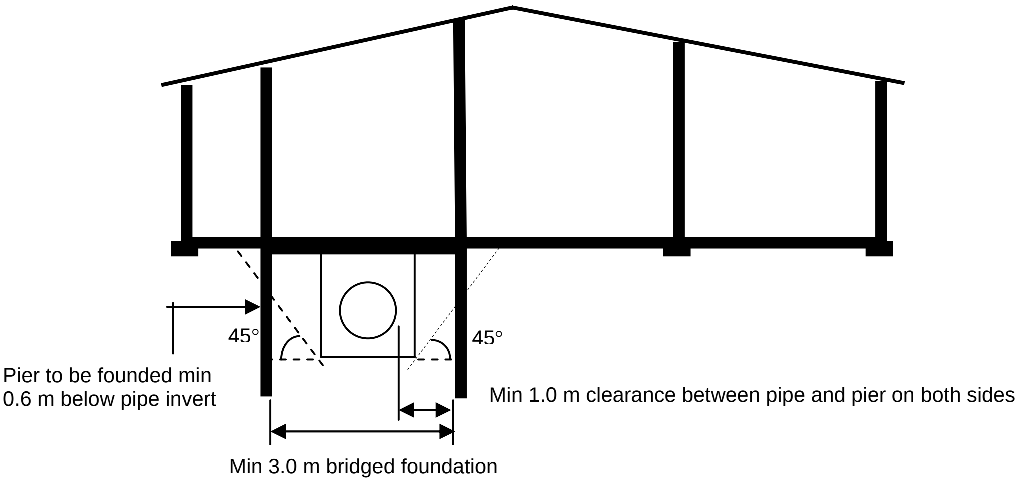
For development constraints on aboveground stormwater facilities, refer to Chapter 1 of Part A of this document. For suspended structures over aboveground stormwater facilities such as overland flow paths, a 2.0 m undercroft height clearance (2.5 m height if finished floor levels are referenced) is required for unimpeded flow conveyance and for maintenance purposes. Inundated areas under the buildings must paved and adequate scour protection provided elsewhere.

[2] Undercroft is measured from the floor to the lowest appurtenance on the ceiling ie bearers, fire sprinklers, overhanging pipe systems, light fixtures, signs, etc.

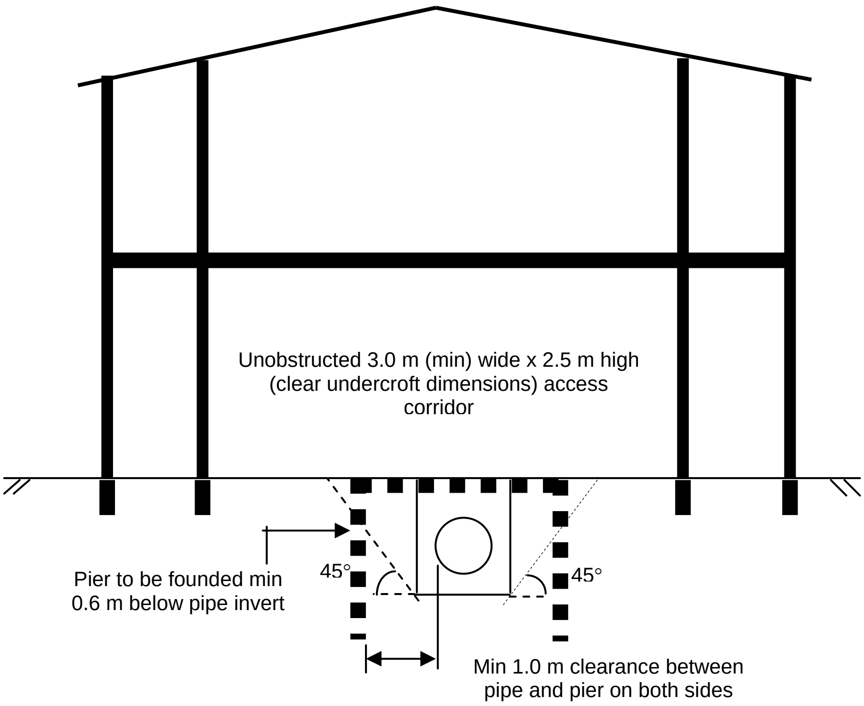
Case 1 (preferred): Structures located clear of aboveground and underground stormwater facilities either on existing or diverted alignment



Case 2: Slab on ground structures built over stormwater pipe



Case 3: Suspended structures built over stormwater pipe



3.0 DESIGN PARAMETERS

3.1 GENERAL

The following factors must be considered in the design and selection of the final drainage treatment:

1. Design discharges based on the ultimate development in the catchment.
2. Future maintenance requirements to ensure the drainage facility continues to meet its design performance.
3. Safety of persons particularly children.
4. Erosion and siltation both within and on adjoining properties not increased as a result of the development.
5. The existing treatments of other sections of the drainage system.
6. The general amenity of the area and particular use of parkland.
7. Environmental issues, including vegetation protection orders (VPOs), maintenance of natural channels and buffer vegetation, preservation and rehabilitation of flora and fauna habitats, riparian vegetation, archaeological values, heritage values, water quality and existing features such as wetlands.
8. Integration of total water cycle management.

3.2 DESIGN STORMS

In certain situations where no internal road dedications are proposed, drainage of stormwater from road reserves fronting the site may discharge onto and through the subject subdivision toward or along a defined natural watercourse. This stormwater must be managed in such a way as to preserve the amenity of the allotments that are affected. Easements are required over drainage outlets from road reserves (minimum 10 metres in from the property alignment by 3 metres wide).

The major and minor drainage systems as described in Section 5.03 of *QUDM* forms the basis of the drainage system within the urban area. The design standards are given in Table B2.1.

The major drainage system is that part of a drainage system in a catchment that is designed to convey rare design storms. The system may comprise open space floodway channels, road reserves, pavement expanses, overland flow paths, natural or constructed waterways, detention/retention basins and other major water bodies. Where the major system is within the road reserve, the design standard is the 50 year ARI storm event.

The minor drainage system is that part of a drainage system in a catchment that controls flows from the minor design storm such as the 2 year ARI and 10 year ARI events. The system usually comprises kerbs and channels, roadside channels, gully inlet pits, underground pipes, manholes and outlets.

TABLE B2.1 DESIGN STANDARDS FOR MAJOR/MINOR DRAINAGE SYSTEMS

Development category	Design parameter	Design standard
2-5 dwelling units per hectare (typically in Rural/Environmental Protection Areas where predominant uses include house on large allotment and farm)	Minor drainage system Major drainage system	Minimum 2y ARI Minimum 50y ARI (less piped flow if applicable)
>5 and ≤ 20 dwelling units per hectare (typically in Low Density Residential Area comprising mainly one or two storey single houses)	Minor drainage system Major drainage system Roofwater drainage	Minimum 2y ARI Minimum 50y ARI (less piped flow if applicable) Level II *QUDM* Section 5.13.4
>20 dwelling units per hectare (typically in Low-medium to High Density Residential Areas comprising multi-unit dwellings)	Minor drainage system Major drainage system Roofwater and lot drainage	Minimum 10y ARI Minimum 50y ARI (less piped flow if applicable) Level III and IV *QUDM* Section 5.13.4
Industrial areas	Minor drainage system Major drainage system Roofwater and lot drainage	Minimum 2y ARI* Minimum 50y ARI (less piped flow if applicable) Level IV *QUDM* Section 5.13.4
New use centre activities (incorporating a wide range of commercial, retail and residential uses)	Minor drainage system Major drainage system Roofwater and lot drainage	Minimum 10y ARI Minimum 50y ARI (less piped flow if applicable) Level IV and V *QUDM* Section 5.13.4
Major roads (district access, suburban route, arterial route, major industrial access through road)	Kerb and channel flow Cross drainage (culvert) flow Roadway flow width & depth limits	Minimum 10y ARI To suit flood immunity requirement of Chapter 1 of Part A of this document Refer *QUDM* Table 5.04.1
Minor roads (local access, neighbourhood access, minor industrial access)	Kerb and channel flow Cross drainage (culvert) flow Roadway flow width & depth limits	Refer relevant development category, minimum 2y ARI To suit flood immunity requirement of Chapter 1 of Part A of this document Refer *QUDM* Table 5.04.1

* For industrial roads that will be major through roads, the minor drainage design will need to increase to 10 y ARI.

3.3 URBAN DRAINAGE

3.3.1 Fraction Impervious

The coefficient of runoff for the 10 year ARI storm event is given in Table B2.2.

TABLE B2.2 C_{10} VS DEVELOPMENT CATEGORY

Development category	C_{10}
Central business	0.90
Commercial and industrial	0.88
Significant paved areas (eg roads and carparks)	0.88
Low-medium to high density residential areas (Note 2)	0.87 (Note 2)
Low density residential area (mainly one or two storey single houses, including roads) Average lot ≥ 750 m^2 Average lot ≥ 600 m^2 < 750 m^2 Average lot ≥ 450 m^2 < 600 m^2 Average lot ≥ 300 m^2 < 450 m^2	 0.82 0.85 0.86 0.87
Low density residential area (mainly one or two storey single houses, excluding roads) Average lot ≥ 750 m^2 Average lot ≥ 600 m^2 < 750 m^2 Average lot ≥ 450 m^2 < 600 m^2 Average lot ≥ 300 m^2 < 450 m^2	 0.81 0.82 0.83 0.85
Rural/ environmental protection areas (2-5 dwelling units per hectare)	0.74
Open space (eg parks)	0.70

NOTES:
1. Table B2.2 above combines *QUDM* Tables 4.05.1 and 4.05.2.
2. This area is designated for mainly multi-unit dwellings with density >20 dwelling units per hectare. The designer can determine the actual fraction impervious for the particular development under consideration and calculate the coefficients of runoff from these values. Alternatively use C_{10} = 0.87.

3.3.2 Time of Concentration

Refer *QUDM* Section 4.06. The time of concentration should take due account of partial area effects in accordance with *QUDM* Section 4.03.2, particularly where there is open space within a residential area or for developments with significant directly connected impervious areas.

Standard inlet times (*QUDM* Section 4.06.4) should be used in an urban catchment starting in a developed area. The standard inlet time represents the time taken for runoff from the extremes of the catchment boundary to reach the underground drainage system. The referenced average slopes are the slopes along the predominant flow paths for the catchment in its developed state.

The kinematic wave and the Bransby-Williams equations should not be used to estimate overland flow time. Similarly the Friend's equation should be used with caution for urban catchment starting in bush or parkland. The Friend's equation should not be used if flow concentration is expected to occur, even if this flow concentration occurs as a result of minor rill erosion.

Unless the actual velocity in the drainage system upstream is determined, the adopted pipe velocity should not be less than 3 m/s for the purpose of estimating pipe travel time.

For small open creek catchments (< 100 ha), minor channel or creek flow times may be initially determined by assuming an average stream velocity of 1.5 m/s. For medium sized open creek catchments (100-500 ha), the Department of Main Roads stream velocity method (*QUDM* Table 4.06.5) or the modified Friend's equation (*QUDM* Section 4.06.11) may be used. For large open creek catchments (> 500 ha), the Rational Method should be used with extreme caution. However, detailed hydrological modelling of Brisbane's major creeks indicate that the Rational Method provides a reasonable peak flood discharges if an average flow velocity of 0.9 m/s is assumed.

3.3.3 Pipe and Material Standards

Refer *Reference Specification S160 Drainage*. Materials that will be accepted for use in stormwater pipes include:

- Steel reinforced concrete pipe, minimum Class 2.
- Fibre reinforced concrete pipe, minimum Class 1.
- Type B flexible polypropylene/polyethylene pipe, minimum stiffness Class SN8 (PP SDR 23 or PE SDR 21).
- UPVC sewer pipe minimum Class SN6 for roofwater drainage.

3.3.4 Roof and Allotment Drainage

Refer Section 3.2 and *QUDM* Section 5.13. See Standard Drawing UMS 351 for conventional residential subdivisions and Standard Drawing UMS 154 for WSUD residential subdivisions. See Standard Drawing UMS 353 for developments pertaining to material change of use such as Community Titles Scheme, commercial and industrial developments.

3.3.5 Public Utilities and Other Services

Refer *QUDM* Section 5.14. See the relevant Standard Drawings UMS 121, UMS 122, UMS 123, UMS 124 or UMS 151 for the recommended locations of public utilities.

3.3.6 Rainfall Intensity

Refer *QUDM* Section 4.07.

TABLE B2.3 RAINFALL INTENSITY FOR BRISBANE

Duration (Minutes)	**Average Recurrence Interval**						
	1 year mm/h	**2 year mm/h**	**5 year mm/h**	**10 year mm/h**	**20 year mm/h**	**50 year mm/h**	**100 year mm/h**
5.0	117	151	191	215	248	291	325
5.2	116	149	189	212	244	287	320
5.4	114	147	186	209	241	283	316
5.6	113	145	184	207	238	279	312
5.8	111	143	181	204	235	276	308
6.0	110	141	179	202	232	273	304
6.2	108	139	177	199	229	269	300
6.4	107	138	175	197	227	266	297
6.6	106	136	173	195	224	263	294
6.8	105	135	171	193	222	261	291
7.0	103	133	169	190	219	258	288
7.2	102	132	167	189	217	255	285
7.4	101	130	166	187	215	253	282
7.6	100	129	164	185	213	250	279
7.8	99	128	162	183	211	248	277
8.0	98	126	161	181	209	246	274
8.5	96	123	157	177	204	240	269
9.0	94	121	154	173	200	236	263
9.5	92	118	150	170	196	231	258
10.0	90	116	147	167	192	227	253
10.5	88	113	145	164	189	222	249
11.0	86	111	142	161	185	219	244
11.5	85	109	139	158	182	215	240
12.0	83	107	137	155	179	212	237
12.5	82	105	135	153	176	208	233
13.0	80	104	133	150	174	205	229
13.5	79	102	131	148	171	202	226
14.0	78	100	129	146	169	199	223
14.5	77	99	127	144	166	196	220
15.0	75	97	125	142	164	194	217
15.5	74	96	123	140	162	191	214
16.0	73	95	122	138	160	189	211
16.5	72	93	120	136	158	186	209
17.0	71	92	118	134	156	184	206
17.5	70	91	117	133	154	182	204
18.0	69	90	115	131	152	180	201
18.5	68	88	114	129	150	178	199
19.0	68	87	113	128	148	176	197
19.5	67	86	111	126	147	174	195
20.0	66	85	110	125	145	172	193

Duration (Minutes)	Average Recurrence Interval 1 year mm/h	2 year mm/h	5 year mm/h	10 year mm/h	20 year mm/h	50 year mm/h	100 year mm/h
20.5	65	84	109	124	143	170	191
21.0	64	83	108	122	142	168	189
21.5	64	82	106	121	140	166	187
22.0	63	81	105	120	139	165	185
22.5	62	81	104	118	137	163	183
23.0	62	80	103	117	136	161	181
23.5	61	79	102	116	135	160	179
24.0	60	78	101	115	133	158	178
24.5	60	77	100	114	132	157	176
25.0	59	76	99	113	131	155	174
26.0	58	75	97	111	128	152	171
27.0	57	74	95	108	126	150	168
28.0	56	72	94	107	124	147	165
29.0	55	71	92	105	122	145	162
30.0	54	70	90	103	120	142	160
31	53	68	89	101	118	140	157
32	52	67	87	100	116	138	155
33	51	66	86	98	114	136	152
34	50	65	85	96	112	133	150
35	49	64	83	95	111	131	148
36	49	63	82	94	109	130	146
37	48	62	81	92	107	128	144
38	47	61	80	91	106	126	142
39	47	60	79	90	104	124	140
40	46	59	77	88	103	123	138
45	43	56	72	83	97	115	129
50	40	52	68	78	91	108	122
55	38	49	64	74	86	103	115
60	36	47	61	70	82	97	110
90	28	36	47	54	63	76	85
120	23	29	39	45	52	62	71
150	19	25	33	38	45	54	61
180	17	22	29	34	39	47	53
210	15	20	26	30	35	42	48
240	14	18	24	27	32	39	44

Based on coefficients issued by the Bureau of Meteorology(Ref FN2615) for 27475 S 152025 E
Calculated in accordance with Australian Rainfall and Runoff (1997 Edition)

3.3.7 Drainage Calculations

Refer *QUDM* Section 5.16. Hydraulic calculations must be included on all drawings in tabular form, generally in accordance with Figure B2.1.

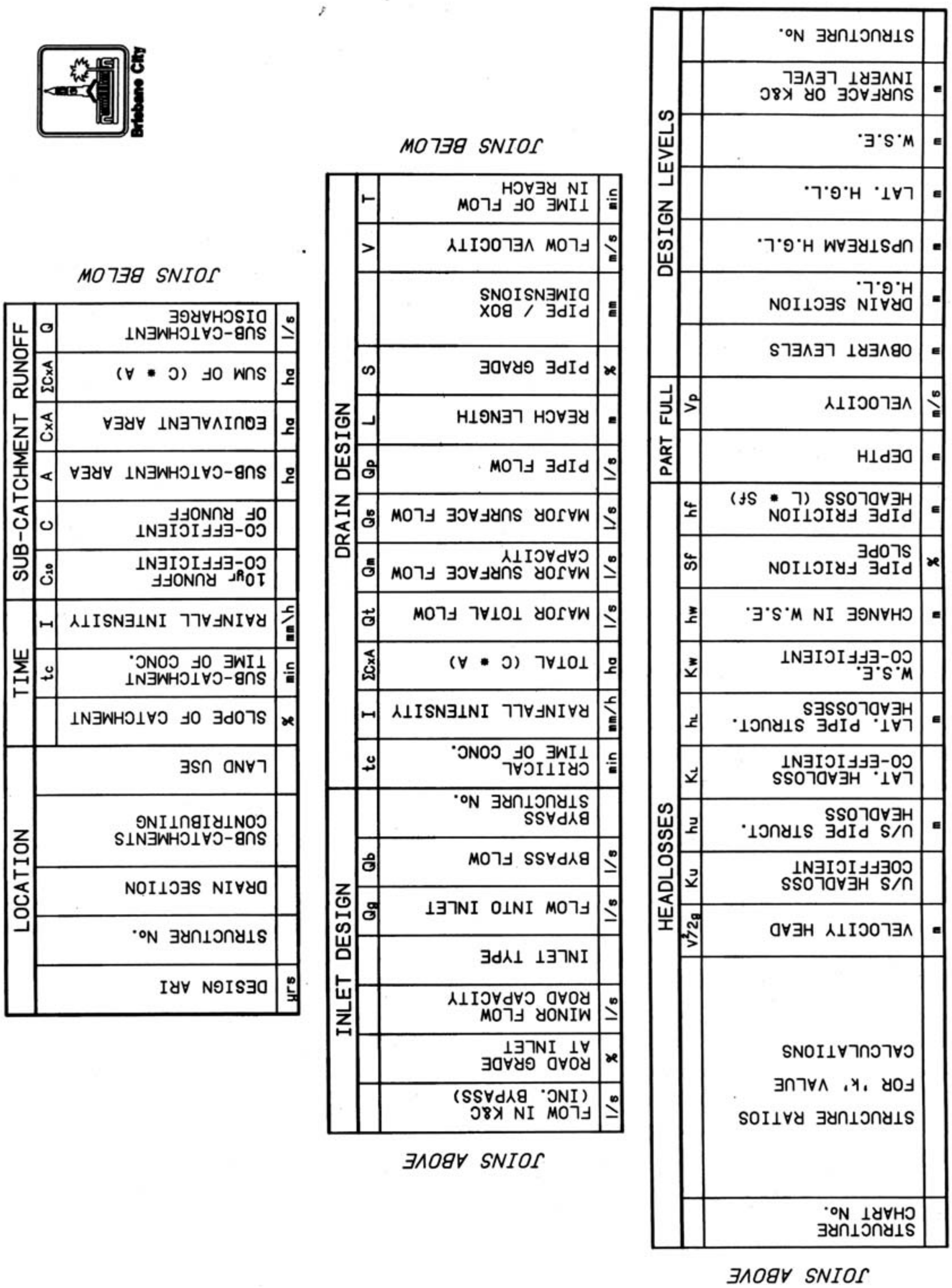


FIGURE B2.1
DRAINAGE CALCULATIONS

CHAPTER 2 STORMWATER DRAINAGE

3.3.8 Gully Inlet Capacity Charts

Refer Standard Drawings UMS 381 to UMS 392 for the relevant hydraulic capture charts.

3.4 TAILWATER LEVEL

Tidal outfalls (ocean and bays)

Refer *QUDM* Section 7.03.1. The design tailwater level is the Mean High Water Springs (MHWS) plus 0.3 m to offset the potential effects of climate change, for all storm events.

Non-tidal outfalls

Refer *QUDM* Section 7.03.3. The design tailwater level is the maximum level determined by the following methods:

- The combined peak discharge is determined from rainfall intensity corresponding to the time of concentration for the side drain.
- The combined peak discharge of the side drain and main stream is determined from rainfall intensity corresponding to the time of concentration of the receiving waters.

Tidal outfalls (rivers and creeks)

Refer *QUDM* Section 7.03.2. Design tailwater level should include an appropriate flood surcharge corresponding to the combined discharges (as per non-tidal outfalls above) to the MHWS. An additional allowance of 0.3 m is required to offset the potential effects of climate change.

Drowned outlets

Drowned outlets should not be used without the approval of Council Delegate.

4.0 WATER SENSITIVE URBAN DESIGN

4.1 GENERAL

Water Sensitive Urban Design (WSUD) incorporates the sustainability principles of water conservation, waste minimisation, and environmental protection, to the management of the urban water cycle. At various points along the drainage system, controls or combination of controls are used to manage the quality and quantity of stormwater so that the impact on the environment and existing drainage systems are managed. Also refer Chapter 1, Part C - Water Quality Management Guidelines, in this document.

4.2 RAINWATER TANKS

Brisbane City Council actively supports the use of rainwater tanks as they provide a simple and effective means for property owners to manage stormwater at the source, whilst providing a major benefit to the management of the urban water cycle through reduced water demand and improved water quality. The application of rainwater tanks is particularly suited to new and existing houses, small-scale residential developments of four dwelling units or less. Council has developed an information kit that provides the minimum requirements for garden watering or connection to toilets, hot water system, or the laundry. Overflows from rainwater tanks are usually connected to soakage or rubble pits.

The combined rainwater tank/soakage pit system is also suited to older areas of the city where there is no stormwater connection point and the lot falls away from the street. The proposed stormwater disposal method should mitigate any potential impacts of worsening the existing conditions either by ponding, concentrating or increasing the flow onto adjoining properties. The acceptable solution may include soakage trenches or a combination of gravity feed pipe via a drowned outlet to the kerb and channel and/or rainwater tank under the house. The soakage pit should be located at least 3 metres from any building or boundary, and to provide every opportunity for the stormwater flow to broad sheet across the lawn. The removal of stormwater by adsorption or infiltration into permeable soils should be designed to suit the topography and soil type.

4.3 ROAD DESIGN

Conventional road drainage consists of kerb and channel and gully pits that drain the road surfaces and adjoining lots into an underground pipe system. This system efficiently collects and conveys stormwater runoff into the underground drainage system.

With the water sensitive design approach, runoff from more frequent storms is collected and treated within WSUD devices (such as swales and bio-retention systems) to allow for some attenuation of the flow and to facilitate the retention of contaminants prior to these flows discharging to receiving waterways. Refer to publication *Water Sensitive Urban Design Engineering Guidelines: Stormwater* (Brisbane City Council, August 2005) for details on design principles and application.

4.4 NATURAL CHANNEL DESIGN

The basic principles of Natural Channel Design (NCD) are to maintain the hydraulic conveyance requirements of engineered or affected channels, while improving environmental values. NCD is important in all waterways (whether natural in formation or constructed to appear and operate as natural channels), especially where the waterway provides a link with bushland reserves or forms an important part of an aquatic or terrestrial movement corridor. An **extended maintenance period** may be required until the channel has sufficiently stabilised and vegetative cover is well established. Refer to publication *Natural Channel Design Guidelines* (Brisbane City Council, 2003) for details on design principles and application.

Where rock armour is required to control erosion, partially embedded or grouted natural rocks/boulders should be used. Planting between rocks can soften visual impacts. Boulders placed on the bed of the watercourse can promote habitat diversity. Boulders recessed into the low flow channel or the pools can increase the total submerged surface area, thus increasing the available food supply for aquatic life. Concrete lining is generally unacceptable to Council as this solution does not protect nor enhance environmental values.

5.0 INFRASTRUCTURE REQUIREMENTS

5.1 RECONFIGURING A LOT

5.1.1 General

Provision should be made within subdivisions for roof and surface water to be satisfactorily discharged. Whilst in most cases piping to the street or to an underground pipe system may be the best solution, the applicant should nevertheless consider alternative ecologically sustainable solutions outlined in Section 4.

5.1.2 Low Density Residential Areas

Lots falling to the street

In residential streets, an approved full height kerb adaptor should be provided in the kerb, 400 mm from the projected low side boundary for each lot. In collector roads or in streets where footpaths will be constructed, kerb adaptors as per above with a length of UPVC pipe (sewer class SN8) extended from the adaptor to beyond the concrete footpath is required as per Standard Drawing UMS 354.

Lots falling away from the street

All lots that do not fall directly towards the road should be provided with a rear allotment roofwater drainage system. This system will also be required where lots fall towards parkland. Roofwater drainage systems will be classified as private drains with the responsibility for future maintenance lying with the property owners. This system is detailed in Standard Drawing UMS 351.

Easements in favour of Council will be required over roofwater lines as shown in Table B2.4. An easement is required irrespective of pipe size when the roofwater line is designed for more than 3 lots. Refer Section 2.4 - Easements. The pipes at each property may be sized in accordance with *QUDM* assuming 10 L/s for each 180 m^2 of roof.

TABLE B2.4 EASEMENTS OVER ROOFWATER LINES

No. of lots (nominal 180 m^2 roof area at each lot)	Minimum pipe diameter	Easement width	Minimum pipe slope
1-3	150 mm	Not required	1.0%
4-6	225 mm	1.5 m	0.5%
7-10	300 mm	1.5 m	0.5%

Roofwater inspection pits

Roofwater inspection pits should be in accordance with Standard Drawing UMS 352. Roofwater pits/rnanholes should be provided every 100 m and/or at changes in pipe sizes and/or where direction changes more than 15° and/or where the line terminates.

Connection points

At least one connection point should be provided on the main line for each property. This connection should be in the form of Y-junctions or directly into an inspection manhole with the property branch line diameter being a minimum of 100 mm. Engineering drawings should have dimensions to show the exact location of the connection points.

Discharge points

Generally, all rear of allotment (roofwater) drainage reticulation systems of this nature should discharge into the back of a suitably located stormwater gully or manhole in the street. Where the private roofwater reticulation system outlet is so isolated from a stormwater gully or manhole that connection is not reasonable, discharge may be allowed into the kerb and channel from an inspection manhole or inspection opening located 0.6 m maximum inside the property.

The maximum permissible discharge to the kerb and channel should be limited to 30 L/s (ie maximum 3 single house lots), and twin 100 mm diameter pipes (equivalent 150 mm diameter) with approved kerb adaptors should be used. Unless approved otherwise by Council Delegate, discharge into the high side kerb of a one-way crossfall street is generally not permitted. Consideration will only apply to single house roofwater drains.

Kerb adaptors

Only approved full height kerb adaptors, complying with *Reference Specification S150 Roadworks*, are permitted in Brisbane City. The Class C (medium duty) kerb adaptors should be used in local access and neighbourhood access roads, and the Class D (heavy duty) kerb adaptors used on industrial access and higher order hierarchy roads. The kerb adaptors should be placed in a location where service pits on the footpath will not conflict with the future pipe location.

Where hot dipped galvanised RHS is used as an alternative to prefabricated kerb adaptors, the ends of the section protruding through the kerb should be cut flush with the face of the kerb and treated with an appropriate corrosion treatment.

5.1.3 Industrial/ Commercial/ High Density Residential Areas

The level IV drainage connection requires the provision of a minimum 600 mm diameter inspection manhole (refer Standard Drawing UMS 353) inside the lot at the low side boundary, with a minimum 375 mm diameter pipe connecting to a suitably located stormwater gully or manhole in the trunk drainage network. All lots that do not fall directly towards the road should be provided with a rear allotment drainage system that discharges into the back of a suitably located stormwater gully or manhole in the street.

5.2 MATERIAL CHANGE OF USE

5.2.1 General

Scope

Developments pertaining to material change of use include Community Titles Scheme, commercial and industrial developments.

Driveway grids

The use of collection grids across driveways at the property boundary is not permitted unless approved by Council Delegate. (Driveway grids usually require high maintenance. The inevitable lapses in maintenance can lead to potential blockage, which may cause inconvenience to road users during a heavy storm.) Wherever possible, the paved area should be shaped in such a manner so as to divert the runoff towards grated field inlets. If driveway grids are used, these must be bolted down.

Connection to kerb and channel

Level III drainage (connection to kerb and channel) is only permitted if the total discharge from the development including any external catchment does not exceed 30 L/s. Full height kerb adaptors in accordance with Section 5.1.2 should be provided where practicable. Alternatively, multiple hot dip galvanised rectangular hollow sections (RHS) 125/150/200 mm wide x 75 mm high can be used. In multi-unit residential developments, circular pipes may be used only if there is sufficient depth of cover and depth of kerb and if approved by Council Delegate.

Pipe size and type

The minimum pipe size for internal underground site drainage is 150 mm nominal diameter. Where the pipe also conveys stormwater from an adjoining upstream property (now or in future), the minimum pipe size is 225 mm diameter.

The pipe types and classes should comply with the following requirements.

- Domestic applications (low density residential) should be in accordance with *AS 1254 - UPVC Pipes and Fittings for Stormwater and Surface Water Applications*.
- Commercial, industrial, medium and high density residential applications should be in accordance with *AS 1260 – PVC Pipes and Fittings for Drain, Waste and Vent Applications*. The minimum pipe class is UPVC sewer class SN6.

Pipe drainage systems

Where the existing underground pipes that service the external catchments traverse the site, these pipes must be preserved from damage or structural loading (refer Section 2.6). In the absence of an Infrastructure Charges Plan that specifies the development contribution for stormwater facilities and where the existing drainage system is inadequate, the Developer is generally responsible for upgrading the pipe drainage to the appropriate design standard in accordance with these Guidelines. Easements will be required in accordance with Section 2.4. In all cases where there is developable land upstream of the site, the development must provide a suitable drainage inlet for future upstream developments and consider these fully developed catchment flows in their design. Further cut-off drains and the like should be provided to prevent overland flow from adjacent properties causing problems on the developed land.

Localised overland flow paths

All developments must provide an overland flow path for the Q_{50} design storm less the piped flow. Refer Section 5.3 for design limitations. In residential developments where the difference in levels of the dwelling adjacent to the local overland flow path is minimal, calculations must be provided to demonstrate that the habitable floor levels have the required immunity.

The development must not cause ponding of stormwater or nuisance from discharge of stormwater on adjoining properties. Filling, retaining walls, buildings, fences, or other obstructions should not block overland flow. Furthermore these obstructions must not cause the overland flow to be diverted to, or concentrated onto, another property.

Channels and watercourses

If open cut channels and natural watercourses are permitted within the site, easements including access areas adjacent to the channel will be required.

5.2.2 Roof and Surface Water Hydraulic Requirements

Development of a site requires the design and construction of a drainage system to collect roofwater and surface water runoff from within the site and runoff from external catchments traversing or concentrated on the site, and to discharge the water to a lawful point of discharge. Even though the focus of this section is on the conventional underground pipe drainage system, the alternative water sensitive urban design techniques should be considered.

Pipe drainage of on-site roofwater and surface water from paved and unpaved areas should comply with *AS 3500.3*, *QUDM* Section 5.13 Level III, IV and V, and Standard Drawing UMS 353. Pipes should be located clear of any driveways and should not cross footpaths in front of adjoining properties.

The internal pipe drainage system is required to collect the discharge from individual roofwater systems and from the paved common areas, including internal roads and parking bays. If the pipe drainage system collects only 'internal' runoff and roofwater, the system is a private drainline and is owned by the property owners. In these circumstances, no easements will be required. Where the underground drainage system collects water from an external road reserve, the drainline ownership should be formally transferred to Council and easements provided.

Provision must be made for the future orderly development of upstream properties with respect to pipe drainage. The need for future developments having to resort to pumping of stormwater to a discharge point rather than by gravitational drainage must be avoided. Pipe drainage must be installed to allow for the future connection by adjoining properties when they are developed, which, by virtue of topography and/or existing developments, should discharge stormwater by gravity feed through the subject site. This drain must be a minimum 225 mm diameter (300 mm diameter for industrial) running from the boundary to the discharge point and be covered by an easement, a minimum of 1.5 m wide, in favour of Council.

If drainage cannot be gained by a gravity system a pump will be required. Refer Section 2.5 - Pumped Stormwater Drainage.

5.3 OVERLAND FLOW PATHS

5.3.1 General

The *Brisbane City Plan* defines an overland flow path as:

- Where a piped drainage system exists, the path where floodwaters exceeding the capacity of the underground drainage system would flow.
- Where no piped drainage system or other form of defined watercourse exists, the path taken by surface runoff from higher parts of the catchment. This does not include a watercourse or gully with well defined banks.

Any proposed development, especially those involving filling, needs to take account of existing or created overland flow paths and make due provision in the design. Overland flow paths must be clearly indicated on the drawings.

Developments within any overland flow paths are generally not permitted unless the applicant can satisfactorily demonstrate compliance with all the flood immunity and trafficability requirements set out in Chapter 1 of Part A of this document.

In residential subdivisions, overland flow paths must be located in roadways, parks or pathways and not through private allotments. Details and calculations are required when overland flow within the road reserve is directed into narrow pedestrian pathways. Calculations should demonstrate that overland flow does not enter the adjacent blocks during the 50y ARI flow.

Council will not permit substantial blockage (eg by filling or erection of buildings and retaining walls) of overland flow paths to be offset by the provision of an underground drainage system to convey major overland flows. This alternative is unacceptable for the following reasons:

- Additional maintenance costs to Council.
- Loss of storage.
- Potential adverse flooding impacts in extreme storms.
- Safety hazards at inlets and outlets.
- Major adverse flooding impacts when inlets are blocked.

Drainage calculations, cross sections and plan layouts, should be provided for any proposed overland flow path. The Consultant must ensure that the as constructed levels are consistent with those shown on the approved engineering drawings.

In site developments such as apartment buildings or townhouses where the sites are filled to provide suitable falls to the roadway, the Developer must pay particular attention to the preservation of existing overland flow paths, the obstruction of which may cause flooding or ponding of stormwater on adjoining properties. Particular attention must also be given to overland flow in many of the older inner city areas, as the underground drainage may not meet current standards and there is the likelihood of substantial overland flow paths being associated with the route of the pipe drains through properties. Overland flow paths should be located along the driveways (usually applies to built up inner city areas) and protected by an easement.

Special attention should also be paid to localised overland flow and site drainage in small lot subdivisions or where 'built to the boundary' building envelopes will apply. Additional pipe drainage, easements and concrete lined drains may be required along the rear boundary in such situations.

In all circumstances, easements will be required for overland flow paths within private properties. Proposed easements for the design overland flow should be shown on the engineering drawings. Refer also Section 2.4 - Easements.

5.3.2 Design Criteria

Overland flow paths not in designated channels (channels usually have clearly defined bed and banks) must conform to the following requirements for the 50 year ARI design storm event.

- A depth velocity product of no greater than 0.6 m^2/s (0.4 m^2/s applies to high risk areas where there is an obvious likelihood of injury or loss of life).
- A maximum depth of 0.3 m applies to vehicular accommodation (limited to uncovered short term car parking bays or unclosed car parking associated with a house) and access areas.

Development levels of residential properties must be set using a Manning's 'n' of 0.10 to take into account of any future planting and garden beds that may occur, ancillary structures (eg fences, sheds) that may be erected, and any other obstructions that cannot be regulated.

5.4 UNDERGROUND PIPE DRAINAGE

5.4.1 Pipes

≥ 375 mm diameter

All Council owned drains must be 375 mm diameter or greater. The following types of pipes, conforming to *Reference Specification S160 Drainage*, are acceptable to Council.

- Steel reinforced concrete pipes.
- Fibre reinforced pipes. These are preferred in situations where the pipe may be subject to tidal waters.
- Type B flexible pipes. Polypropylene/polyethylene pipes or fittings with plain inside surfaces and a solid or hollow helical or annular ribbed or corrugated external surfaces.

< 375 mm diameter

Generally pipes within these diameters are used as roofwater drainage pipes. Fibre reinforced concrete or UPVC (minimum sewer class SN6 should be used for inter-allotment roofwater drainage) pipes should be used. Galvanised steel RHS are required from development sites across the footpath to the kerb and channel, if permitted.

Pipe grade limits

The minimum grade of 1%, as specified in AS 3500.3 – Stormwater Drainage, will apply to pipes ≤150 mm diameter. The minimum grade of 0.5% will apply to pipes 225-300 mm diameter. The minimum grade of 0.3% will apply to pipes ≥375 mm diameter. For flow velocity and pipe grade limits, refer *QUDM* Sections 5.11 and 5.12.

CCTV inspection

A closed circuit television camera (CCTV) inspection is required shortly (no more than two weeks) before the On Maintenance inspection and prior to the formal acceptance of On Maintenance, to demonstrate that the standard of the constructed stormwater system is acceptable to Council. The CCTV inspection report and video must be viewed by an RPEQ prior to submission to Council. Any defects that require attention should be identified and remedial measures recommended by the RPEQ. Remedial measures for all defects identified must be submitted to Council for approval. Once the remedial measures have been completed, a follow up survey is required to demonstrate that they have been carried out to Council's satisfaction. Refer to Section 2.6.3 for more details.

Pipe cracking

During the 1994/95 and 1997 audits carried out by Council on a number of subdivisions, the problem of premature cracking of concrete stormwater pipes was found to be widespread in pipes smaller than 900 mm diameter. The major cause was attributed to pipe overload by construction equipment rather than typical service loads for which the pipes were designed. Compliance with all the following criteria is required to counteract premature pipe cracking.

1. The design and selection of the pipe type and class must consider construction loading (compaction equipment and construction traffic), which is usually the critical load case for pipes <900 mm diameter.
2. Drainage plans issued for construction must show, for each drainline, the following:
   - Pipe type and class.
   - Installation type.
   - Construction method (layer thickness, compaction plant).

   Design aids available from concrete pipe manufacturers may be used and are recommended. These include software for calculation of loads on pipes to *AS 3725*, tables and charts. It is recommended that charts showing the relationship between compaction equipment and pipe class are also included with the engineering drawings.
3. Delivered pipes and installed pipes must comply with the inspection and acceptability criteria detailed in *Reference Specification S160 Drainage*.
4. CCTV inspections.

5.4.2 Pipework Layout

Underground stormwater pipework layout should, in most cases, be the conventional herringbone layout.

5.4.3 Gully to Gully Drainlines/ Gully Manholes

In the gully to gully systems, pipes are connected between gully pits instead of manholes, with both the inlet and outlet pipes connected to the gully pit walls. (Note: The conventional gully pit has only the outlet pipe connection to the main trunk drainage line). Refer Figure B2.2.

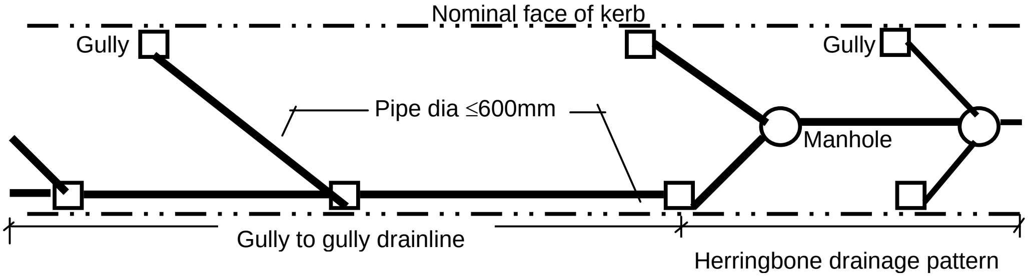


FIGURE B2.2
TYPICAL GULLY LAYOUT

Gully to gully drainlines are acceptable for pipes 600 mm diameter or less, provided that all the following Council requirements are satisfied.

1. Gullies are consistent with Council's standard drawings.
2. Acute angles in connecting pipes are avoided to minimise head losses.
3. Potential interference with other utility services on the footpath is avoided.
4. The major drainage line (spine) of the gully to gully system is constructed on one side of the road only. Any gullies on the opposite side of the road should be connected directly across the road. Under no circumstances are spines of gully to gully systems permitted on both sides of the road.
5. The gully pit is appropriately benched.

Gully manholes in Brisbane City are not permitted without written approval from the Principal Engineer Strategic Infrastructure Management. The stringent approval process ensures that Council's performance and maintenance objectives are met to maximise the serviceability of the asset, and to achieve sustainable level of ongoing maintenance and replacement program by using standardised components to the maximum practicable extent.

Gully manholes may be approved subject to compliance with all the following criteria.

1. The inlet and manhole is at the same point eg at the sag of the road.
2. It is the only alternative to a multi-grated inlet eg in relief drainage works where utility services locations pose major constraints.
3. Written advice from the responsible utility authority is submitted, stating that the existing services will preclude the construction of the conventional herringbone drainage pattern.
4. Council's standard components such as lintels and grates should be used wherever possible. Hydraulic analysis and structural testing data should accompany any request for approval to use alternative components.

5.4.4 Manholes/ Chambers

Manholes and chambers must be provided in accordance with Standard Drawings UMS 321 to UMS 329. Fixed ladder access in accordance with *AS 1657* must be installed to manholes/chambers >3.0 m deep. Step irons must be installed to manholes/chambers with depths between 1.35 m and 3.0 m.

Unless approved otherwise by Council, the desirable minimum and maximum manhole depths should be limited to 1.2 m and 3.0 m respectively. The nominated maximum depth of 3.0 m is based on the upper physical limit of undertaking an inspection without entering the manhole, as any person entering a manhole must conform to safe working procedures for confined space. Other workplace health and safety provisions that may apply to deep manholes include intermediate landing and ladder cage requirements.

The minimum distance between inlet pipes into a manhole or chamber is 150 mm. Benching is required on the floor of manholes (usually half the diameter of the outlet pipe) in order to properly direct the flow of water and prevent silt build up in the corners.

Precast manholes from an approved supplier may be used provided they are installed in accordance with the manufacturer's recommendations. The access hole diameter must conform to Council's standards. Chambers will require certification by a Registered Professional Engineer Queensland (RPEQ).

5.4.5 Inlets/ Outlets

Inlets and outlets should be provided generally in accordance with Standard Drawings UMS 341 and UMS 342. Where safety is an issue precautionary measures must be incorporated. Pillar inlets will be required as temporary inlets at stage boundaries. Special consideration is necessary at inlets and outlets to ensure all measures are taken to produce structures that are safe, with low maintenance and fitting in with the amenity of the area. Reference should also be made to the publication *Stormwater Outlets in Parks and Waterways Guidelines* (Brisbane City Council, 2003) for design guidance.

5.4.6 Gullies/ Field Inlets

Field inlets (Standard Drawing UMS 337) are usually constructed using standard gully grates or headwalls with a concrete apron surround. The size of field inlets must be designed with an expected 50% blockage. Special consideration will be necessary in regard to safety, maintenance and amenity of the area. A raised grated inlet with a lock down grate may be used where debris is expected. However, raised horizontal screens are generally not acceptable adjacent footpaths, bikeways or public accessible areas.

Standard gullies must not be located on sharp horizontal curves (≤10 m kerb radius). New gullies must be constructed in accordance with Standard Drawing UMS 330. The lip in line gully offers improved bike-safe feature and rideability, reduced maintenance costs, hydraulic efficiencies in most applications, and ease in pavement construction. Lip in line gullies are generally undesirable in areas subject to high pedestrian traffic (eg bus stops, taxi ranks, passenger set down zones, shop fronts, etc) unless appropriate measures are implemented (eg landscaping and installing street furniture on the verge) to restrict public access to the gully. The use of kerb in line gullies (Standard Drawing UMS 331) must be limited to established areas where the existing verge widths are narrow (generally less than 2 m) or where pedestrian impacts cannot be managed in a satisfactory manner.

Special attention must be considered at turnouts, to ensure the gully is not required in the turnout. The depth to the pipe crown at the gully pit must be a minimum of 0.45 m, noting that this dimension is not the minimum cover required for construction and service loadings to the pipe. Unless approved otherwise by Council, the desirable maximum gully depth must be limited to 1.35 m to enable safe maintenance access without the aid of step irons.

Antiponding gullies in accordance with Standard Drawings UMS 334 and UMS 335 are only permitted in special circumstances at intersections when the road geometry does not allow the kerb and channel to drain to the standard gully at the tangent points. The inlet capacities of these gullies must be excluded from the calculations.

Precast gully tops from an approved supplier may be used provided they are installed in accordance with the manufacturer's recommendations.

5.5 SURFACE DRAINAGE

5.5.1 Overland Flow Paths

Overland flow paths will need to be designed considering the following points:

- Depth by velocity product and maximum flow depth should not exceed the specified values in Section 5.3.
- The surfacing should prevent erosion.
- The ongoing functionality should not be affected.
- The amenity of the area should not be affected.

In new subdivisions, overland flow paths are not permitted through private property and must be restricted to parks or road reserves or pathways. Overland flow paths within parks must be designed to ensure safety, useability for park purposes when dry, high visual quality, and ease of maintenance.

5.5.2 Table Drains

Table drains are generally only permitted in the road reserve for rural locations and when a new half road is constructed. In these instances, table drains are required to manage the road runoff in the absence of kerbs and channels. Table drains must be separated from the carriageway by regularly spaced delineator posts. To prevent erosion and to minimise maintenance, table drains must be free draining and designed in accordance with the *Table Drains Erosion Control Guidelines* (Brisbane City Council, January 2001).

5.5.3 Swales

These drainage structures are used to collect and improve the water quality of runoff. Care needs to be taken that collected water is not directed in a concentrated form onto adjoining properties. The long term functionality of the device must be considered. Refer to publication *Water Sensitive Urban Design Engineering Guidelines: Stormwater* (Brisbane City Council, August 2005) for details on design principles and application.

5.6 OPEN CHANNELS

5.6.1 General

Designed open channels should not only satisfy hydraulic requirements, but also to enhance the environmental and amenity aspects of the area. In addition to the design requirements set out in Section 8.00 of *QUDM*, the following requirements of Sections 5.6.2, 5.6.3 and 5.6.4 will also apply. The preferred treatment for open channels should be in accordance with the publication *Natural Channel Design Guidelines* (Brisbane City Council, 2003).

CHAPTER 2 STORMWATER DRAINAGE

5.6.2 Types of Designed Open Channels

The Stormwater Management Code of the *Brisbane City Plan* promotes the use of natural channel design and water sensitive urban design principles (refer Section 4.4). Alternative treatments of channels should be considered and discussed with Council Delegate prior to commencement of design.

Where grass lined channels are proposed the aesthetic value of these channels should be enhanced by the liberal inclusion of native canopy trees. The tree species and planting density should be selected to enable:

- Easy maintenance (mowing).
- Sufficient light penetration to not only sustain the grass cover but also minimises weed growth.

The hydraulic conveyance of a drain under major flows should be designed to include the impacts of long term vegetal growth. The possible effects of scouring at the grass/concrete interface as indicated in *QUDM* should be assessed and works to overcome any problems should be incorporated in the proposal. The use of linear wetlands and off-line wetlands whilst encouraged, needs to be agreed to by Council Delegate. Care should be taken to ensure that the wetlands do not continually run dry.

5.6.3 Manning's Roughness Coefficients

Manning's 'n' for a grassed open channel is determined by a number of factors including vegetal retardance and hydraulic radius. The table and charts set out in *QUDM* Section 8.04 provide sufficient correlation to determine Manning's n for most developments.

Council's minimum landscaping requirements for open channels dictates a minimum Manning's 'n' of 0.08 although greater values may be directed by Council where deemed appropriate. A sensitivity analysis should always be undertaken for a Manning's 'n' of 0.15 to ensure the freeboard is not exceeded in a design.

Table B2.5 provides a semi-quantitative approach towards the evaluation of various Manning's roughness coefficients. Source reference: *Natural Channel Design Guidelines* (Brisbane City Council, 2003).

TABLE B2.5 FLOODPLAIN REVEGETATION DENSITY GUIDELINES FOR VARIOUS MANNING'S ROUGHNESS VALUES

Manning's 'n'	Description
0.03	Short grass with the water depth >> grass height.
0.04	Short grass with the water depth >> grass height on a slightly irregular earth surface. Trees at 10 m spacing and areas are easy to mow.
0.05	Long grass on an irregular (bumpy) surface with few trees and irregular ground could make grass cutting difficult. Alternatively, trees at 8 m spacing on an even, well grassed surface, no shrubs, no low branches.
0.06	Long grass, trees at 6 m spacing, few shrubs. Easy to walk through vegetation. Area not mowed, but regular maintenance is required to remove weeds and debris.
0.07	Trees at 5 m spacing, no low branches, few shrubs, walking may be difficult in some areas.
0.08	Trees at 4 m spacing, some low branches, few shrubs, few restrictions to walking.
0.09	Trees at 3 m spacing, weeds and long grasses may exist in some locations. Walking becomes difficult due to fallen branches and woody debris.
0.10	Trees at 2 m spacing, low branches, regular shrubs, no vines. Canopy cover possibly shades weeds and it is difficult to walk through.
0.12	Trees at 1.5 m spacing with some low branches, a few shrubs. Slow to walk through.
0.15	Trees and shrubs at 1 m spacing, some vines, low branches, fallen trees, difficult and slow to walk through. Alternatively, a continuous coverage of woody weeds with sparse leaves and no vines.
0.20	Trees and shrubs at 1 m spacing plus thick vine cover at flood level and fallen trees, very difficult to walk through. Alternatively, a continuous coverage of healthy shrubs and woody weeds from ground level to above flood level.

5.6.4 Hydraulic Considerations

All hydrologic and hydraulic calculations for major watercourses or creeks for the purpose of determining ultimate flood levels and development fill and flood levels are based on:

- Q_{100} flows for a fully developed catchment. The effects of lesser flows should also be investigated.
- A fully vegetated waterway corridor using a Manning's n of 0.15, unless the scope of full revegetation is not possible due to an unacceptable increase in flood levels. The restricted revegetation areas are usually identified in available Council studies such as the Stormwater Management Plans, Waterway Management Plans, and Flood Studies. In general, the planting of trees and shrubs impedes the passage of flow, thereby leading to increased flood levels. The high vegetal roughness coefficient allows for generally unrestricted planting of vegetation.

The proposed development should not cause any adverse flooding, nor make matters worse with respect to flooding of developed or developable areas, erosion potential, or the general amenity of the area. The Developer should not assume that the downstream drainage will be upgraded at a future date thereby allowing its proposal to be of a lower standard. Developers cannot rely on future maintenance by Council to support a proposal.

5.6.5 Velocity

An open channel with critical or supercritical conditions is not acceptable. The velocity should be limited to less than 90% critical velocity in the major storm event. The maximum velocity allowed in an unlined channel is set out in *QUDM* Section 8.07 for earth and vegetated channels and should not exceed 2 m/s unless approved by Council Delegate.

The velocity used to determine the time of concentration for the designed channel should not be less than the velocity in the design channel or alternatively, an average value of 2 m/s is adopted. Unless the actual velocity in drainage system upstream is determined, the adopted pipe velocity should not be less than 3 m/s.

Channel velocity checks should assume that downstream undersized culverts will be upgraded to current design standards at some time in the future. The afflux caused by any roadway crossing over a watercourse should not affect the adjoining properties.

5.6.6 Freeboard

Refer flood immunity levels specified in Chapter 1 of Part A of this document and *QUDM* Section 8.03.

5.6.7 Batters, Landscaping and Maintenance Access

The side slope of the channel banks should not be steeper than 1V:4H (vegetated) and the preferred side slope is 1V:6H (grassed or vegetated). Boulders can be provided intermittently in localised areas to improve the aesthetic appearance of the channel.

Landscaping of the open channel is very important from a visual amenity perspective and future maintenance. The Developer should submit landscape plans prior to hydraulic calculations commencing so that Council is satisfied that the channel will be a feature and not merely ‘a drain’. The preferred treatment for designed open channels should be in accordance with the publication *Natural Channel Design Guidelines* (Brisbane City Council, 2003).

Berms of 6.0 m (minimum) should be provided along each side of the open channel for maintenance, environmental and recreational purposes. Access locations to potential trouble spots within the channel should also be provided.

5.6.8 Minimum Longitudinal Grades

If a channel is proposed in a low lying drainage problem area where grades are relatively flat (minimum velocity 0.6 m/s), the submission must consider the sensitivity of the proposed waterway/channel to siltation which may cause eventual flooding of surrounding land. The hydraulic analysis must include the effects of siltation in the order of 150 mm having been deposited. The provision of a concrete invert and access to facilitate the removal of sediment must be considered. A further consideration is the provision of silt traps at the head of the drain to minimise the environmental effect of silt removal along the full drain lengths.

5.6.9 Outfalls and Outlets

Pipe drainage outfalls to open channels and natural creeks must be designed to control the discharge velocity to spread the concentrated discharge to avoid erosion to the bed and banks and to enhance the water quality by stripping contaminants. Plunge pools are more desirable at outlets on environmental and aesthetic grounds. Outlet diffusers must be set back into the creek bank to allow for future migration or erosion of the creek. Similarly manholes must not be located on the assumption that the creek morphology is stable. Reference should also be made to the publication *Stormwater Outlets in Parks and Waterways Guidelines* (Brisbane City Council, 2003) for design guidance.

5.6.10 Energy Dissipators

Energy dissipators to control the outlet velocity should be designed using a recognised design practice and supported with calculations and references to the chosen design method. Generally plunge pools with rock bottoms are preferred over baffle blocks, as the latter may pose a safety hazard if any children are trapped in the stormwater drain during a storm.

Energy dissipators should be free draining. Designs based upon downstream ponding are not generally recommended; however, such design will be considered if health and maintenance aspects have been adequately addressed. Debris collection around baffle blocks should be a design consideration. It should be noted that wide baffle blocks would trap less debris than narrow blocks.

The spacing between blocks transverse to the flow should be designed to suit individual site conditions. Spacing between transverse blocks would normally be at least 1.5 times the block width, the spacing between consecutive baffle blocks parallel to the direction of flow being at least 4 times the block height if fully drowned conditions are assumed to occur around the blocks.

Energy dissipators, outlets and drop structures etc, when located in parkland, should address aesthetics, maintenance and safety issues. Refer the publication *Stormwater Outlets in Parks and Waterways Guidelines* (Brisbane City Council, 2003) for further details.

5.6.11 Drop Structures

Drop structures may be divided into two categories (ie high drop when the depth of flow < drop height or low drop when the depth of flow > drop height). Generally drop structures should be avoided where environmental concerns are an issue, for example, where aquatic life, migratory routes, and faunal corridors are to be maintained within a creek. Drop structures should also be avoided wherever possible for safety reasons.

There is only a limited amount of literature available for the design of drop structures and generally this literature is restricted to the design of drops in rectangular channels. The use of trapezoidal or irregular shaped channels can introduce a three-dimensional flow pattern if the approach flow is allowed to accelerate toward the drop. Experience has shown that this flow pattern can significantly reduce the efficiency of the downstream hydraulic jump, resulting in a submerged jet that is unable to be modelled by simple hydraulic calculations.

It should therefore not be assumed that a hydraulic jump would occur downstream of a non-rectangular drop structure. Similarly it should not be assumed that uniform flow conditions exist near any drop structure. Fully drowned drop structures can be analysed by a simple backwater analysis using appropriate expansion/contraction loss coefficients and representative cross sections.

Guidelines (if applicable) for the design of drop structures can be obtained from the following references:

- Brisbane City Council, 2004, *Erosion Treatments for Urban Creek Guidelines*.
- *Urban Storm Drainage - Criteria Manual Vol. 2*. Denver Regional Council of Governments Ed. Wright - McLaughlin Engineers, March 1969.
- *Training Workshop on Integrated Urban Stormwater Management Vol 3,* AWWA Canberra Branch and Hydrological Society, Canberra Ed. Brett C. Phillips.
- Peterka, A.J. 1984, *Hydraulic Design of Stilling Basins and Energy Dissipaters*, U.S. Department of the Interior Bureau of Reclamation Engineering Nomograph No. 25, Washington, U.S.A.
- *Water Under the Bridge - Aspects of Culvert Design - Part 1*. G.M. Witheridge, R. Tomlinson.
- *Drop Structure Design Problems*. G.M. Witheridge.

Where several drop structures are required to descend a steep grade reference should be made to the design of stepped spillways. A suitable reference being:

- *Hydraulic Design of Stepped Spillways*. CIRIA Report 33 I.T.S. Essery and M.W. Horner

Council preference is that drop structures be cast in situ reinforced concrete or natural rocks. Rock filled mattress type protective works has created maintenance problems in the past and are only to be considered under special circumstances.

5.6.12 Service Crossings above Channel Bed

Isolated service pipe crossings located above the bed are not allowed where such a structure will affect visual amenity. If Council is satisfied that visual amenity is not compromised, afflux from the structure should not exceed 150 mm and is contained within the site area. It is preferable that the level of the crossing be as low as possible or above the flood level. The crossing should be designed to avoid debris collection and to take account of scour at the bank entry or in the bed below the pipe.

5.6.13 Service Crossings below Channel Bed

Pipe crossings which are located below the bed of an unlined channel should have at least one metre clear cover or additional scour protection may need to be provided along the open channel in the vicinity of a pipe crossing. If mitigation works have already been undertaken on the watercourse or if the channel is in a stable condition, this requirement may be relaxed at the discretion of Council Delegate, provided appropriate protection works are undertaken. The Consultant's submission should include a plan and cross section of the proposed works and a longitudinal section of the bed.

5.6.14 Erosion Control

The possible effects of scouring at the interface of lined and unlined sections should also be incorporated to the proposal. For more information about erosion and sediment control in general, refer to Part C - Water Quality Management Guidelines, of this document.

5.7 FOULWATER LINES

Foulwater lines used to drain both the greywater and roofwater from properties. When the sewerage reticulation network in Brisbane was constructed, the greywater was redirected to sewer but the roofwater remained connected to the foulwater lines. However new stormwater connection to foulwater lines is not permitted, nor is it acceptable to assume that these lines are redundant. Therefore the proposed development should not damage these lines and any proposed diversion should connect to the stormwater system.

5.8 CONCRETE INVERT AT ROAD INTERSECTION

The use of concrete invert (generally along line of the through street) at any road intersection is not permitted. Instead the road geometry should be designed to accommodate an underground drainage system of gully pits/manholes and pipes as appropriate.

5.9 DETENTION AND RETENTION SYSTEMS

5.9.1 General

When a development is likely to increase runoff to such an extent that the downstream drainage cannot cater for the additional capacity or adverse impacts are created, it may become necessary to incorporate a detention basin. These basins can be either dry (detention basin) or wet (retention basin). Off-line basins can lessen the risk of a sequential over-topping. Both types may have multiple uses eg pollution control, environmental wetland, recreational, as well as hydraulic functions. Also refer Part C - Water Quality Management Guidelines, of this document. As a general rule, larger detention storage is usually required at the top one-third of the catchment, no detention storage is required at the bottom one-third of the catchment, and intermediate requirements at the middle part of the catchment.

A community-based asset (such as from a subdivision) must be located in Council owned or Council controlled land. Council approval of the location is required at the conceptual design stage.

Detention systems on private land (on-site stormwater detention systems) will only be permitted in developments pertaining to material change of use such as Community Titles Scheme, commercial and industrial developments. The registered proprietor(s) of the lot(s) is required to enter into a covenant pursuant to Section 97A of the land Title Act 1994, with Brisbane City Council as Covenantee, to ensure management of the on-site stormwater detention system is in accordance with the approved report and plans. (Note: A statutory covenant cannot deal with matters subject to an easement.)

Aboveground detention basins are preferred as it is considered that they are more readily maintained than underground storage facilities. Council will not support the installation of on-site underground detention facilities unless there is no alternative suitable above ground option, nor will Council support underground detention facilities on public land.

The floor of the detention basin should be well graded to prevent permanent ponding. A minimum grade of 0.7% applies to underground storage and paved areas, and a grade of 1.5% to landscaped areas.

5.9.2 Data Requirements

The detailed design submission must be prepared and certified by an RPEQ suitably qualified in the field of drainage/hydraulic investigations. The following information must be included in the submission:

- Calculations for each storage.
- Where WSUD components are proposed, calculations and details of both the detention/retention system and WSUD components are required to demonstrate the interaction of the integrated system.
- Calculations verifying that the flow paths/floodways, drainage systems and any overflow weirs have sufficient capacity.
- Design plans (refer Section 2.11 of Chapter 2 of Part D of this document for details).
- Maintenance plan (refer Section 5.9.12 below).

5.9.3 Design Approach

The design of retention/detention basins should be undertaken in accordance with *QUDM* Section 6, unless the specific requirements of this chapter or other Council references dictate otherwise.

5.9.4 Sizing

Runoff routing and reservoir (basin) routing calculations are required to estimate the size of the detention basin, where the inflow and outflow hydrographs for a range of storm duration for the design ARI events are determined. Initial sizing may be undertaken, using manual techniques, in order to determine the order of magnitude of the storage required. However the final sizing should be completed with the aid of computer models such as DRAINS (ILSAX), RAFTS, or RORB.

In addition to local catchment analysis, the assessment should also demonstrate that the detention basin proposal is sustainable on a catchment wide basis. Where the detention storage has limited outlet capacity, the impact of antecedent rain on the available storage should be considered. Antecedent conditions should be based on the actual rainfall records from the closest meteorological station. Where required, Council can provide information on these ‘duration independent storms’.

5.9.5 Overland Flows

Overland flows that enter the site from surrounding properties should be collected and conveyed through the development, but kept isolated from the any on-site detention basin systems for all storm events.

5.9.6 Hydraulic Control

On-site detention should be gravity drained. Pumped systems are not permitted. However alternatives such as suspended pipelines and recycled stormwater would be considered, but the onus is on the designer to provide details on permanency of construction, reliability of performance and suitable aesthetic treatment.

An important element in preserving the integrity of on-site detention system is ensuring that the system functions independently of the street drainage network. The on-site facility is not intended to handle surcharge flow from the street drainage network. Due to the possibility that the street system could surcharge, the starting hydraulic grade line level of the detention system should be set at the top of the kerb and channel at the discharge point to the street system. The outlet control device should be set above this level regardless whether the detention system is connected to the underground drainage system or to the kerb and channel, to ensure that the on-site facility is unaffected by downstream hydraulic grade line or water surface levels.

5.9.7 Visual Aesthetics

Once authorised to have a basin in parkland or other Council controlled land, an important design criterion is that the basin does not look like a hydraulic structure but rather has special character. This will involve the use of variable slopes, the retention of upstream gullies, the camouflage of inlets and outlet structures and the like. A rectangular or geometrically shaped basin is generally undesirable. Landscape plans must be lodged for approval.

Detention storage in open space areas within a development must not be visually intrusive but incorporate a variety of plant species. The facility must not be located in the front yard unless it is a visual feature. The maximum height difference between the natural ground level and the basin invert must be limited to 0.5 m.

5.9.8 Embankments

Grassed and landscaped embankments should not be steeper than 1V:6H and 1V:4H respectively. The selected use of boulder retaining walls is encouraged to provide variety. In some instances (eg occurrence of rapid drawdown), geotechnical investigations/designs may be required to assess the embankment stability.

5.9.9 Inlets and Outlets

General

Low-level outlet structures generally consist of orifice plates (fixed to pipe inlets) or culverts placed at a low level in the basin to cater for the discharge of normal outflows. The diameter of the low flow outlet pipes should not be less than 375 mm. High-level outlet structures should cater for the discharge of major or extreme outflows. Overflow weirs or spillways should be designed to convey the 100y ARI peak discharge, assuming that the basin storage is full and the low-level outlet(s) are blocked. The overspill should not inundate nor concentrate flows onto adjoining properties.

Discharge control pits

Discharge control pits should be located in a suitable position and designed to achieve the following performance characteristics.

- Minimise risk of debris blockage.
- Can be readily inspected.
- Can be accessed for cleaning.
- Minimise risk of vandalism.

The minimum pit size of 600 mm x 600 mm (to internal wall dimensions) should be restricted to a depth of less than 0.8 m. For pits exceeding 0.8 m depth, the minimum size should be 600 mm x 900 mm. Step irons are required for pits exceeding 1.35 m depth. Subsoil drainage should be provided around discharge pits in aboveground storage systems to prevent the ground from becoming saturated during prolonged wet weather.

A sump is required in the base of the discharge control pit to assist in minimising turbulence near the pit floor from affecting the hydraulic performance of the orifice outlet. The sump would also prevent silt and debris from blocking the orifice outlet and facilitate simple installation of the orifice plate. The invert of the sump should be at least 1.5 times the orifice diameter or 200 mm (whichever is greater) below the centre of the orifice outlet. Sufficient weepholes should be installed in the sump floor and be kept unblocked.

Orifice plates

Orifice plates should be manufactured from corrosion resistant stainless steel plate with a minimum thickness of 3 mm (5 mm where orifice diameter exceeds 150 mm), with a central circular hole machined to 0.5 mm accuracy. The orifice diameter should not less than 35 mm and the machined hole should retain a sharp edge. The plate should be permanently fixed to the pit wall and epoxy sealed to prevent the entrance of water around the edges. The plates should be engraved with the orifice diameter and an identifying mark, and the orifice diameters certified by the manufactures.

Grates and trash screens

The intake to a detention basin outlet should be protected against blockage and to reduce hazard for persons trapped in the basin during a storm. Inflows to the orifice should be screened.

Screening (hot dipped galvanised) should be provided at a rate of not less than 50 times the orifice diameter, and incorporate handle(s) for easy removal. Generally, galvanised Lysaght RH3030 Maximesh (or approved equivalent) with galvanised angle steel frame is suitable for use as an internal trash screen to small on-site detention basins. The screens should be fixed at least 150 mm from the orifice and positioned as close to vertical as possible. Pits up to 0.6 m depth should have screens no flatter than 45°. In pits over 0.6 m depth or in remote positions, the installation angle should be increased to 60°.

For aboveground detention storage, the grates should be set inconspicuously into the embankments of the basin. Vegetated screenings should be provided, but these should not affect the hydraulic performance of the inlet and outlet structures.

5.9.10 Underground Storage

Underground detention facilities are not preferred and may not be feasible in many areas of the City where the storage levels are below the controlling downstream hydraulic grade line. The design of underground detention storage should address a number of public health and pollution issues. The storage should be self-cleaning, well ventilated, does not cause accumulation of noxious gas, and facilitate easy maintenance and inspection. The following requirements should be met in order to achieve the performance objectives.

- The base has a suitable fall to the outlet (minimum grade 0.7%) and is appropriately shaped to prevent permanent ponding.
- Provision of a minimum 600 mm x 1000 mm maintenance access opening. The lifting weight of the grated lid should not exceed 20 kg.
- Installation of step irons to storage pits greater than 1.35 m depth.
- Where the storage is not sufficiently deep (< 1.2 m), access grates should be placed at the extremities of the tank and at intervals not exceeding 3 m. This should allow any point in the tank to be flushed or reached with a broom or similar implement, without the need to enter the tank.
- The minimum clearance height for accessible tanks is 1.2 m. Tanks less than 0.75 m high must be precast to avoid difficulties with removing formwork.
- To enable visual observation of the entire base of the storage pit, at least 30% of the roof surface area should be grated. Grates should be a minimum of 600 mm wide by 1000 mm long, and arranged in a continuous lengths along the storage pit. Both the access point and the grated areas should be secured to prevent public access.

5.9.11 Safety and Amenity

The danger to children moving in and out of the basin during times of inundation should be carefully considered. The outlet/inlet grates should be designed such that any child will be able to crawl away from the grate under all operating conditions. Dense landscaping can be used to deter access.

Sensitive signing should be erected at strategic locations alerting people to the possible hazards of the detention basins. Where detention basins are located directly upstream of a dedicated roadway or residential property, safety and damage consequences as a result of basin collapse or overtopping to the road users/residents should be carefully evaluated.

The maximum depths of ponding in the detention storage facility should be limited to minimise safety hazards and preserve amenity values.

- Public parkland: 20y ARI ponded depth of 1.2 m.
- Parking or paved areas: 50y ARI ponded depth of 0.3 m.
- Unfenced landscaped areas: 50y ARI ponded depth of 0.5 m.
- Underground storage: No depth limit.
- Fenced areas: No depth limit.
- Roof areas: Depth limit dictated by structural integrity or usage (such as rooftop car parking).

5.9.12 Maintenance Plan

All detention and retention systems must be designed with simple, safe, cost-effective maintenance in mind. A maintenance plan that documents all the maintenance requirements and responsibilities must be developed in parallel with the design process. The plan must set out how the system should be maintained by addressing issues such as inspection, likely clean-out frequency, procedures, access, occupational health and safety requirements, and likely annual maintenance costs.